U.S. Coast and geodetic survey

36th Congress, 2d Session. } SENATE. { Ex. Doc.

REPORT

OF

THE SUPERINTENDENT

OF THE

COAST SURVEY,

SHOWING

THE PROGRESS OF THE SURVEY

DURING

THE YEAR 1860.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1861.

LETTER

FROM THE

SECRETARY OF THE TREASURY,

TRANSMITTING

The Report of the Superintendent of the United States Coast Survey.

IN THE SENATE OF THE UNITED STATES, *January* 21, 1861.

Resolved, That there be printed six thousand two hundred copies of the Report of the Superintendent of the Coast Survey for the year 1860, one thousand two hundred of which for the use of the Senate, and five thousand for distribution by said Superintendent; and that the same be printed and bound with the charts and sketches in quarto form; and that the printing of said charts and sketches shall be done to the satisfaction of the Superintendent of the Coast Survey.

ASBURY DICKINS, *Secretary.*

TREASURY DEPARTMENT, *December* 20, 1860.

SIR: I have the honor to transmit, for the information of the Senate, a report made to the department by A. D. Bache, LL.D., Superintendent of the United States Coast Survey, stating the progress in that work during the year ending November 1, 1860, and showing, by the accompanying map, the general progress made in the survey; also the manuscript map of progress prepared at the Coast Survey Office, in accordance with the act of Congress approved March 3, 1853.

With great respect, your obedient servant,

PHILIP F. THOMAS,
Secretary of the Treasury.

Hon. JOHN C. BRECKINRIDGE,
Vice-President of the United States and President of the U. S. Senate.

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ERRATA.

In Coast Survey Report for 1859.

Page 73, line 11 from below, for "*western*" read *eastern.*
Page 98, line 7 from top, for "*frustrum*" read *frustum.*
Page 98, last line, for "*reading*" put *value.*
Page 145, line 15 from bottom, for "*Thunderbolt*" read *Humboldt.*
Page 279, line 16, for "40° 50′" read 4° 50′.
Page 280, line 10, for "*for*" read *from.*
Page 293, line 18, for 1840 read *in* 1840.
Page 317, line 19, for "*frustrums* read *frustums.*
Page 359, in title, for "*Sketch No.* 40" read *Sketch No.* 39.

In Coast Survey Report for 1860.

Page 19, line 23 from top, for Lieut. *read* Commander.
Page 54, first line, for inside the shore *read* inside shore.
Page 161, line 12 from below, for having *read* leaving.
Page 239, line 10 from below, for 23s. *read* 28s.
Page 275, line 4 from top, for 25. 18 *read* 23. 22.
Page 275, line 5 from top, for 24. 36 *read* 23. 87.
Page 275, line 7 from top, for 0. 86 *read* 0. 37.
Page 275, line 8 from top, for . 253 *read* . 240.
Page 275, line 9 from top, for 18s. 76 *read* 17s. 52.
Page 275, line 10 from top, for 20 *read* 21.
Page 275, line 14 from top, for 18. 76 *read* 17. 52.
Page 275, line 15 from top, for 29. 30 *read* 28. 06.
Page 275, line 18 from top, for 30. 7 *read* 31. 6.
Page 275, line 21 from top, for 31. 8 *read* 30. 6.
Page 275, line 22 from top, for 29. 3 *read* 28. 1.
Page 275, line 23 from top, for 29. 33 *read* 29. 09.
Page 275, line 24 from top, for 28. 72 *read* 28. 95.

REPORT.

COAST SURVEY OFFICE, WASHINGTON, D. C.,
December 15, 1860.

SIR: As required by law, and by the regulations of the Treasury Department, I have the honor to submit my report on the progress of the Coast Survey of the United States during the surveying year from November 1, 1859, to November 1, 1860.

The progress of the work has been, taking all its branches together, greater than during the year before, but the loss of one of our best steamers by collision at sea has been a sad drawback to the general prosperity of the work. As my estimates for the time of completion of the survey must be materially affected by this loss, I earnestly recommend a special appropriation to replace the steamer at the earliest practicable period.

The survey has again been in progress in its land work, hydrography, or office-work, in the twenty-two seaboard States and territory of the United States. The time of completion on the Atlantic and Gulf of Mexico is now near at hand, and is estimated within a reasonable limit of uncertainty of two years. A continuous triangulation stretches from Passamaquoddy bay to the boundary between North and South Carolina, and another season will make it continuous from Winyah bay to a point below Matanzas river, south of St. Augustine. There remains, in fact, less than one-eighth of the Atlantic coast not covered by one of the classes of triangulation.

In my report of last year I entered very fully into the subject of the time of completion of the survey, and have now only to add that I see no reason to change the statements then and there made, and that if a steam vessel is soon supplied to replace the Walker, I shall be able to make good those statements, unless some new calamity beyond the reach of our estimates overtakes us. The plans are definitely formed in my mind, and require only a steady execution, year by year, to bring them to successful completion. The Coast Survey officers have experience and knowledge, and there is the most cheerful, thorough, and zealous co-operation in every part of the work. The organization has shown itself to be thoroughly effective, and only a fraction of what it has accomplished remains to be done. The portions executing are arranged so as to fit into each other according to a general design, terminating in a complete survey of the coast.

GENERAL STATEMENT OF PROGRESS.

The Atlantic triangulation, as the accompanying sketch (No. 37) shows, is continuous along the coast of twelve States from Passamaquoddy to the boundary of North and South Carolina, a stretch of more than twelve hundred miles, measured in the most general way. With an interval of some fifty-four miles, which is diminished every year by the party at work there, the triangulation is again continuous over the coast of South Carolina to Cumberland sound, on the coast of Georgia, two hundred and eighty miles. Then there is an interval of twenty-seven miles which this season will fill up to the St. John's river, Florida; and the triangles are again continuous to Matanzas inlet, south of St. Augustine. Two parties are working from Matanzas inlet south, and from Indian River inlet north, to fill up that interval, to which a third will next season be added, proceeding north from Cape Florida. Another season or two at most will fill up the whole space from Cape Florida to Cape Sable, and along the keys from

Key Biscayne to Key West and the Marquesas. Charlotte harbor is triangulated, and the work extends from Anclote key to Cedar keys, ninety miles; from Ocilla river, by St. Mark's and Apalachicola, to Cape San Blas, ninety-five miles; over St. Andrew's bay; includes East bay, Maria de Galvez, Escambia, and Pensacola bays; touches the entrance of Perdido bay; extends from Mobile bay one hundred and fifty miles to Lake Pontchartrain, and over Chandeleur and part of Isle au Breton sound to the delta of the Mississippi, the greater part of which it now includes; over Isle Dernière and Caillou bay; over Atchafalaya and Côte Blanche bays; and from East bay (Galveston) two hundred and fifteen miles, passing over Matagorda, Aransas, and Corpus Christi bays and their dependencies, to within one hundred and fifteen miles of the Rio Grande.

The progress on the western coast has not been less satisfactory, taking the newness of the survey there into consideration. It has included all the harbors of California and Oregon, and many of those of Washington Territory, especially those of Washington sound, Puget's sound, and Admiralty inlet, the Straits of Haro and Rosario, and part of the Gulf of Georgia, in the northwest.

Having given, in my letter of last year, a statement of the progress of the astronomical and magnetic work, I need not repeat it here. The longitude problem has been steadily kept in view, and the occurrence of the total solar eclipse, the path of which crossed from the northwestern part of the United States, through Washington Territory and the British possessions, leaving the continent on the coast of Labrador, has been made available for the correction of longitudes and of the lunar tables by parties sent out for the purpose in connexion with those of other departments of the government, and in correspondence with the great astronomical expeditions of Europe.

The number of geographical determinations published by the Coast Survey, exclusive of those made within the past year, is seven thousand one hundred and seventy-eight; the magnetic variations given are upwards of two hundred; the tidal constants for harbors and coasts, one hundred and ten; and the maps and charts of harbors, bays, inlets, sounds, shoals, &c., drawn, engraved, and published, three hundred, exclusive of progress sketches and diagrams.

DIVISIONS OF THE REPORT.

The same division of subjects is retained in this report, as in those immediately preceding, namely: the introduction, the description of operations, and the Appendix.

I. The first part, or introduction, briefly reviews the progress of the year, under separate heads, and contains in detail the estimates to provide for the continuance of the work at the same rate of progress.

II. The field, hydrographic, and office work done during the year is described in detail in the second part of the report, under the head of sections, the Atlantic and Gulf coast being divided into nine and the Pacific coast of the United States into two sections. In each of these the land and hydrographic work is described in geographical order, and the office-work pertaining to each is stated at the head of the section.

III. The Appendix, for convenience of reference, is subdivided in several heads, as—

1. *Field, hydrographic, and office details*, under which are included general lists of the names of officers and the occupation of their parties; the names of officers of the army and navy serving on the work; the items of information furnished in reply to special calls; the field and office statistics of the survey; special developments made by the hydrography of the year, and a general list, including all that have been made in the work; tide-tables for the use of navigators, and detailed reports of the occupation of persons in each of the office divisions, with lists of the engraved maps and charts, and lists of the topographical and hydrographic sheets registered in the office within the past two years.

2. *Special operations and scientific discussions* relative to astronomy, magnetism, and other branches of physical science.

3. *Local surveys*, giving information in regard to the surface features in special localities, and their resources, as bearing on commerce and navigation.

4. *Miscellaneous scientific matter* relative to methods and instruments.

5. *Aids to navigation*, recommended by officers of the survey, and referred generally for the consideration of the Light-house Board.

The condensed statement of progress made within the year, to follow under the next head, is necessary to bring the work under examination as a whole. It shows what the year's estimates have accomplished as introductory to those of the next year but one. Such a statement necessarily excludes details in regard to persons and places which are, nevertheless, essential to the history of the work. The detailed statement in the second part of the report shows the place, time, and amount of the work, and by whom executed. It is but fair that in so arduous a service the officer executing each portion of the survey should be named, and that no one should receive credit for or bear the responsibility of the work of another. Each section forms, as it were, a chapter of the report, of which the introduction gives a table of contents, arranged under the head of each separate operation.

GEOGRAPHICAL SECTIONS.—STATEMENT OF PROGRESS FOR THE SURVEYING YEAR 1859-'60.

I do not conceive it to be necessary to go over the estimates for the completion of the work, section by section, as I stated in my last report the conclusions arrived at, and have no change to make in them. The work is proceeding regularly, and I do not find that my assumed rate of progress for the different operations and localities is too high.

A complete general view of the year's progress will be obtained by consulting the following named documents: 1. The first table (No. 1) of the Appendix, which gives the distribution of the parties in the several sections of the coast, the officers employed, and the general limits of the work done. 2. The general map of the coast, (Sketch No. 37,) showing by characteristic signs the portions surveyed. 3. The detailed maps of each geographical section, from I to XI, lettered A, B, C, &c., with the sub-sketches pointing out the progress in the past year. 4. The brief view which follows these remarks, and which should be read, referring to the sketches mentioned in 2 and 3, according to whether very general or moderately detailed information is desired.

SECTION I. *Coast of Maine, New Hampshire, Massachusetts, and Rhode Island.—(Sketches A, and A bis, Nos.* 1 *and* 2.)—A reconnaissance has been made for connecting the Epping and Fire island bases by the shortest line from *Wachusett —— Beaconpole;* Gunstock, Unkonoonuc, and Wachusett stations have been occupied, and observations for latitude and azimuth, and for the magnetic elements, have been made at the first and third named stations. Observations of the solar eclipse of July 18 for longitude were made at Gunstock, (N. H.;) magnetic observations have been kept up at Eastport, Me., and special determinations of the magnetic elements have been made at Provincetown, Wellfleet, and Chatham, (Cape Cod peninsula.) The triangulation of Passamaquoddy bay has been commenced on a base furnished by the primary work. The triangulation of Frenchman's bay, Me., and of the adjacent coast, has been made in connection with the Epping base, and extended to Pigeon Hill. The triangulation of the entrance of Penobscot bay has been carried to Isle au Haut, and northward on its western side to Camden. The secondary triangulation west of the Penobscot has been completed, including also that of the rivers of Muscongus bay. The topography of the shores of the Sheepscot river, Me., has been completed, and connected with that of the Kennebec; that of Merry-meeting bay has been completed, and plane-table work continued on the Kennebec; that of Casco bay has been continued eastward, from Harpswell to near Cape Small Point; that of Cape Cod bay has been extended east and west from Sandwich, Mass., and westward from

Barnstable harbor. A special plane-table resurvey has been made of the more exposed portions of the islands and shores of Boston harbor, for the city of Boston, and of the neck between Buzzard's bay and Cape Cod bay, for the State of Massachusetts. The in-shore hydrography of the coast of Maine has been extended from the Kennebec entrance eastward into Muscongus bay, and up the Damariscotta river. Off-shore a line has been run from near Cape Ann to Seal island, (Nova Scotia,) outside of the deep-sea lines of last year, and Jeffrey's bank and Jeffrey's ledge have been surveyed. Boston inner harbor to the city, and parts of the outer harbor, have been resurveyed for the city, and detailed tidal and current observations have been connected with the work. The part of Cape Cod bay off the mouth of Scusset river has been sounded out minutely, and currents and tides observed in the same vicinity, and in Buzzard's bay, opposite, for the State of Massachusetts. The tidal observations at Boston navy yard and Eastport, Me., have been continued.

The drawing and engraving of coast map and chart No. 14, from Buzzard's bay to Block island, the drawing of the chart of Portland harbor, and the engraving of preliminary sea-coast chart No. 4, from Cape Cod to Saughkonnet Point, have been completed; as also the engraving of charts of Rockport harbor, Lynn harbor, Muskeget channel, (new edition,) and additions to the progress sketches and plates of charts issued in former years. Progress has been made in the drawing and engraving of preliminary sea-coast chart No. 3, from Cape Small Point to Cape Cod; also on coast maps and charts Nos. 8 and 9, from Seguin island to Cape Ann; on No. 11, from Plymouth harbor to Hyannis harbor; in the drawing of preliminary sea-coast chart No. 2, from Isle au Haut (Penobscot bay) to Cape Elizabeth; in that of the charts of the Sheepscot and Kennebec rivers; on coast map and chart No. 7, from Muscongus bay to Portland harbor; and in the engraving of coast maps and charts Nos. 12 and 13, from Monomoy to Martha's Vineyard.

SECTION II. *Coast of Connecticut, New York, New Jersey, Pennsylvania, and part of Delaware.*—(*Sketch B, No.* 6.)—The triangulation of the Hudson river has been completed to Troy. The topography of the shores has been carried from Piermont and Tarrytown to meet the work of last year at Hastings and Rockland. The topography of Long Island, behind Williamsburg and Rockaway, has been completed. The hydrography of the Hudson river has been extended from Poughkeepsie to Rhinebeck. A resurvey has been made of False Hook shoal (New York bay) for changes; and also of a rocky spot in ten and a half fathoms fifteen miles off the New York light-vessel. The tidal observations at Governor's island and Brooklyn have been kept up. Special magnetic stations have been occupied at Sag harbor, Mount Prospect, and Fire island, (L. I.,) and at Barnegat and Absecom, N. J.

Progress has been made in the drawing and engraving of a map of the Hudson river from New York to Sing Sing, and on coast map and chart No. 21, New York bay and harbor. A chart of Hempstead harbor has been drawn and engraved, and the engraving of coast maps and charts Nos. 15, 16, and 17, Long Island sound, (new edition;) and No. 19, middle part of the southern coast of Long Island, has been completed. Additions have been made to the progress sketch; a separate drawing has been made of Coenties' reef, and a new plate engraved for the chart of Captain's island, east and west.

SECTION III. *Coast of part of Delaware, Maryland, and part of Virginia.*—(*Sketch C, No.* 8.)—The triangulation of the Patuxent river has been completed; that of the Potomac has been extended from Piney Point, upwards, to include Britton's bay. The stations on the Chesapeake have been secured. The topography of Chesapeake bay, at the mouth of Elk river, has been completed; of the Patuxent to the head of tide; that of the St. Mary's has been completed; that of the Potomac has been continued within the limits of the triangulation; that of the North and Ware rivers (Mobjack bay) has been in progress, and that across the peninsula, from Chincoteague to the head of Pocomoke sound, is nearly completed. The hydrography of the Patuxent has been completed, and that of the Potomac extended from the entrance of the river

to Blackstone island. The tidal stations at the Washington navy yard and at Old Point Comfort have been kept up. Views off Cape Henry have been taken for the general coast chart. Special magnetic observations have been made at the Coast Survey office in Washington.

Progress has been made in the drawing and engraving of coast map and chart No. 29, from Isle of Wight (Del.) to Little Machipongo inlet, Va.; and on Nos. 31, 33, 35, and 36, Chesapeake bay; in the engraving of No. 32, Chesapeake bay, from Magothy river to Hudson river, (Md.;) on the chart of the Rappahannock river, and in the drawing of chart No. 30, from Little Machipongo to Great Machipongo inlet; on that of the entrance to James river, and on general coast chart No. IV, from Cape May to Currituck sound. The drawing of the upper and lower, and the engraving of the lower sheet of a preliminary chart of the Patuxent river have been completed; as also the drawing of the chart of St. Mary's river, Md., and the engraving of the preliminary chart of that river has been continued. The plate of the map of York river, Va., has been completed, and additions have been made to the progress sketch.

SECTION IV. *Coast of part of Virginia, and part of North Carolina.*—(*Sketch D, No.* 10.)—The primary triangulation of Pamplico sound, and the secondary connected with it, has been in progress. Topography has been executed near Oregon inlet; from Cape Hatteras to Hatteras inlet, and near Ocracoke. Soundings have been made in Coanjock bay and North river. An off-shore line has been run from Cape Henry to Cape Lookout, crossing the off-shore lines to be run in the section. Views of Cape Hatteras and its vicinity have been drawn for the off-shore chart.

The engraving of coast maps and charts Nos. 40 and 41, Albemarle sound, has been brought up with the field-work; additions have been made to the progress sketch of the section, and miscellaneous work done in retouching and correcting plates. Progress has been made in the drawing of general coast chart No. VI, from Ocracoke inlet to Charleston; on coast map and chart No. 37, from Cape Henry to Currituck sound; on Nos. 46 and 47, from Cape Lookout to Barren inlet; and on preliminary sea-coast charts Nos. 11 and 12, from Cape Hatteras to Cape Fear.

SECTION V. *Coast of part of North Carolina, and coast of South Carolina and Georgia.*—(*Sketch E, No.* 13.)—The primary triangulation has been carried from the Edisto base, southward, to Port Royal sound. The secondary triangulation of the coast of North Carolina has been completed to the boundary between that State and South Carolina; that of the waters connecting St. Helena and Port Royal sounds has been completed; that of the coast of Georgia has been extended from Altamaha sound to beyond the middle of Cumberland island, crossing St. Simon's and St. Andrew's sounds. The topography of the outer islands and inland passage, from Port Royal sound to Savannah river, including the shores of Calibogue sound and part of May river, has been completed; and that of St. Catharine's and Wassaw sound shores has been in progress. Off-shore lines have been run from off Charleston to off Fernandina; Maffitt's channel (Charleston harbor) has been re-examined by request of the city authorities. The hydrography of the inland passage, from St. Helena sound to Port Royal sound, has been completed, as well as that of Ossabaw sound, including the Vernon river to Montgomery, and parts of the Great and Little Ogeechee rivers, and that of the passages to the Savannah river has been in progress. That of Altamaha sound and its dependencies has been nearly completed. The tidal observations at Charleston have been continued with the self-registering gauge.

Preliminary charts of Bull's bay and Port Royal entrance, S. C., and of Sapelo sound, Ga., have been drawn and engraved, and additions made to the chart of Charleston harbor, and to the progress sketch of the section. The drawing of the chart of St. Simon's sound, Brunswick harbor, and Turtle river, has been completed, and its engraving commenced. Progress has been made in the drawing of general coast chart No. VII, from Winyah bay to St. John's river; on that of coast map and chart No. 48, from Barren inlet to Lockwood's Folly inlet, N. C.;

on Nos. 53 and 54, from Rattlesnake shoals to Tripp's inlet, S. C., and on the chart of Ossabaw sound; and the engraving of preliminary sea-coast chart No. 14, from Cape Romain to Savannah, has been continued.

SECTION VI. *Coast, keys, and reefs of Florida.*—(*Sketches F and F bis, Nos.* 15 *and* 16.)—The triangulation along the air line from Fernandina to Cedar keys has been extended from Waldo to Gainsville. The triangulation of St. Augustine harbor has been connected with that of St. John's river, and extended southward to Matanzas inlet; that of Indian river inlet (eastern coast of the peninsula) has been completed; that of Chatham bay, from Pigeon key to Shell key, has been executed, completing the reef triangulation; that of the upper part of Charlotte harbor has been completed, including the adjacent coast of Florida to Boca Nueva. The topography of St. Augustine harbor and its dependencies and approaches has been executed, as also that of Indian River inlet, and that of Charlotte harbor has been nearly completed. The hydrography of St. Augustine harbor and its approaches has been executed; a four-fathom bank, northeast of Indian River inlet, has been sounded, and off-shore lines have been run in the general direction of the coast from Cape Cañaveral, northward. Sections across the Gulf Stream have been made from Indian River inlet and Gilbert's bar across to the Bahama Banks, and from the Tortugas, southwestward, and thence to the coast of Cuba, west of Havana. The hydrography of the Florida reefs and keys has been extended from Grassy key to Lower Matecumbe. Views have been taken for the charts of the Florida reef. A magnetic station has been established at Key West for registering magnetic changes by photography. The tidal observations at the Tortugas have been continued.

The drawing has been completed and the engraving continued of coast map and chart No. 68, from Key Biscayne to Carysfort reef, and No. 71, from Bay Pine key to Boca Grande key. A chart of St. Augustine harbor has been drawn, and progress made in its engraving, as also in the drawing and engraving of general coast chart No. X, from Cape Florida to Cape Sable. The drawing of coast map and chart No. 58, from St. Mary's river to St. John's river; Nos. 69 and 70, from Garden key to Bay Pine key, (Florida reef;) and No. 74, from Lower Matecumbe key to Cape Sable, has been continued. The progress sketches have received additions, and diagrams have been drawn and engraved to illustrate the results of explorations in the Gulf Stream.

SECTION VII. *Part of the western coast of the Florida peninsula.*—(*Sketch G, No.* 25.)—Telegraphic determinations of longitude have been made between Macon, Ga., and Apalachicola, Fla., including Eufaula, Ala., as an intermediate station. The latitude and longitude of Apalachicola have been ascertained, and azimuth observations made for the triangulation. Observations for the magnetic declination, dip, and intensity have been made at Apalachicola and Eufaula. The triangulation has been extended southward from Bayport to Tiger Point, near the Anclote keys; that from Southwest cape across St. Mark's harbor to Ocilla river has been completed; that across St. George's sound has been extended from Apalachicola westward to Cape San Blas; the triangulation of Santa Maria de Galvez and East bays has been completed and connected with the work in Pensacola harbor, and carried over Blackwater bay to Robinson's Point. A preliminary base has been measured, and the triangulation of Perdido bay commenced. The gaps in topography near the entrances of the We-thlocco-chee and Homosassa rivers have been filled. The topography between Ocilla river and St. Mark's, and that westward in Oyster and Dickerson's bays, has been completed, and progress made in the survey of the shores of Crooked river. The topography of the shores of Santa Maria de Galvez, East bay, and part of Blackwater bay has been executed. A hydrographic resurvey has been made of Cedar keys harbor and its dependencies. A line of soundings has been run from Tampa bay to Cedar keys, and from Cedar keys westward, and then north to Pensacola. The hydrography of Apalachicola harbor and of the adjacent parts of St. George's sound has been carried eastward to Cat Point, and supplementary in-shore soundings made from Southwest cape to Crooked

river. The hydrography of Santa Maria de Galvez and East bays has been executed, that of Blackwater bay nearly completed, and soundings from Pensacola harbor through Escambia bay to Live Oak Point. Tidal observations have been kept up with the self-registering tide-gauge at St. Mark's, Dog island, New Inlet, St. Vincent's island, and Warrington navy yard, (Pensacola.) Views have been taken for the charts of Cedar keys, St. George's sound, and Pensacola harbor.

Progress has been made in the drawing of general coast chart No. XIII, Gulf coast from Waccasassa bay to Choctawhatchee bay, Fla.; on preliminary sea-coast chart No. 25, from Santa Rosa sound to Mobile bay; on coast map and chart No. 81, from Chassahowitzka river to Cedar keys; on Nos. 84 and 85, from Ocilla river to Cape St. Blas; and on No. 88, from Choctawhatchee bay to Pensacola bay. The drawing of charts of Apalachicola bay and Escambia and Santa Maria de Galvez bays is now in hand. Additions have been made in drawing and engraving to the chart of St. George's sound, (eastern part;) to that of Pensacola harbor, and to the progress plate. A comparative chart of Pensacola harbor has been drawn, and lines of deep-sea soundings have been added to the general sketch of the Gulf of Mexico.

SECTION VIII. *Coast of Alabama, Mississippi, and part of Louisiana.—(Sketch H, No.* 28.)—The magnetic elements have been determined at three stations on the Mississippi delta and on Côte Blanche island, La. The triangulation of Isle au Breton sound has been carried southward from Point Fortuna, and connected with that of the Mississippi delta on its preliminary base; that of Côte Blanche bay has been pushed westward and completed to the entrance of Vermilion bay. The topography of the shores of Lake Pontchartrain has been carried westward to beyond Ragged Point on the north shore, and to Bayou Le Bar on the south shore; that of the eastern part of the Mississippi delta has included the shores of Passe à Loutre, the North, Northeast, and Southeast Passes and intermediate bays, and Bay Rondo; and that of Côte Blanche bay has been completed. The hydrography of the upper part of Mobile bay to below Dog River bar was executed, and a line of soundings run to the Lower Fleet for comparison with former surveys for the city of Mobile, and elaborate observations of tides and currents were made in the same connection. Passe à Loutre, Northeast, North, and Southeast Passes, were sounded from the head of the passes to the several bars; but the records of this work, with that executed in Chandeleur sound, were lost in the wreck of the steamer Walker. Tidal stations have been established at Passe à Loutre, Southwest Pass, and Isle Dernière, and provided with self-registering gauges. Views have been taken of Chandeleur Island light and of Passe à Loutre entrance and light, for charts of these localities.

The drawing and engraving of coast map and chart No. 91, from Bon Secours bay to Round island, and of the map of the Rigolets, have been completed, and additions made to the progress sketch. Progress has been made in the drawing and engraving of coast map and chart No. 92, from Round island to Grand island, La., and in the drawing of general coast chart No. XIV, from Pensacola bay to the Mississippi delta; and coast map and chart No. 93, from Lake Borgne to Lake Pontchartrain.

SECTION IX. *Coast of part of Louisiana and coast of Texas.—(Sketch I, No.* 32.)—The triangulation of the coast of Texas has been extended southward and westward from Aransas Pass to Laguna Madre, and has been carried over Corpus Christi and Nueces bays. The topography of the shores of San Antonio, Mezquit, and St. Charles bays, and that of the coast embracing St. Joseph's island to Aransas Pass, has been completed, including also part of the shores of Aransas bay. Soundings inside of Matagorda bay have been completed from the entrance northward and eastward to Palacio's Point, and northward to Indianola and Well Point.

Progress has been made in drawing and engraving coast map and chart No. 108, Matagorda and Lavaca bays. The drawing of general coast chart No. XVI, Gulf coast from Galveston bay to the Rio Grande, and that of coast map and chart No. 109, from Matagorda bay to Aransas bay, has been continued, and additions have been made to the progress sketch.

SECTION X. *Coast of California.*—(*Sketches J and J bis, Nos.* 33 *and* 34.)—The triangulation of the coast of Santa Barbara channel has been completed to the town of Santa Barbara from the San Pedro base; preliminary bases have been measured on Santa Rosa and San Clemente islands, and triangulations executed on both, that of the first being completed, and that on the last named nearly so. The primary triangulation north of San Francisco has been extended northward of Russian river, with determinations for latitude, azimuth, and the magnetic elements, and the secondary and tertiary work has included the shores of Tomales and Bodega bays. The topography has been in progress on Santa Cruz island and on the shores of Half Moon bay; that of Petaluma creek (San Pablo bay) has been completed, and the topography of the shores of Drake's bay. Hydrographic surveys have been made at the mouth of Salinas river, (Monterey bay;) on Oakland bar, and at the mouth of Sacramento river. Soundings have been completed off the entrance to San Francisco bay, and the in-shore hydrography has been extended northward beyond Point Reyes, including Drake's bay and lagoon, and Tomales bay. Tidal observations have been kept up at San Diego and San Francisco.

Preliminary charts of San Pedro harbor and Crescent City harbor have been drawn and engraved, and the engraving of the charts of San Francisco bay and Humboldt bay; that of the topography of San Pablo bay and the additions to Alden's reconnaissance have been completed. Additions have been made to the progress sketches, and the drawing of a coast map and chart to include San Francisco bay and harbor has been continued.

SECTION XI. *Coast of Oregon and that of Washington Territory.*—(*Sketch K, No.* 36.)—A preliminary base has been measured, and the triangulation of Gray's harbor executed from its entrance to the mouth of Chehalis river. The preliminary base on Sandy Point, W. T., has been remeasured, and topography has been in progress on the shores of San Juan island, Washington sound. A hydrographic examination has been made at the entrance of Coquille river, Oregon, and tidal observations have been kept up at Astoria.

Additions have been made in drawing and engraving to Alden's reconnaissance of the western coast (upper sheet) and to the progress sketch, and the drawing has been completed for a new edition of the preliminary chart of Washington sound. Progress has also been made in the drawing of a general map and chart to include that sound.

MAPS AND CHARTS.

I have heretofore described the regular series of maps and charts of the coast, which have been projected on three different scales, viz: $\frac{1}{80000}$ for the more detailed maps and charts, representing the coast and the in-shore hydrography; of $\frac{1}{200000}$ for the preliminary charts; and of $\frac{1}{400000}$ for the general coast charts, showing the general features of the coast, and giving the off-shore and the general in-shore hydrography. The computing, drawing, and engraving for these maps have made good progress during the year. The computations have been kept close up to the field-work.

Within the past year one hundred and eleven sheets have been worked on in the Drawing Division. Of this number, nine are finished charts, thirty-nine are coast maps and charts, twenty-one finished maps of special localities, sixteen preliminary, and two of the number are comparative charts. These are exclusive of twenty-four sketches of various kinds. Fifty-six of the sheets referred to have been completed, and fifty-five are in progress. Of those completed, twelve are maps and charts of the first class, and an equal number charts of special localities. Eight of the number are preliminary charts and two comparative charts; and the remaining twenty are sketches, amongst which are included those showing the field progress.

In the Engraving Division eight first class maps and new editions of two have been completed during the year, and twenty-four are in progress. Of this class twenty-two were commenced in previous years and twelve within the present year. In addition, seventeen plates have been engraved of second class charts and sketches, and five plates of that class are yet in hand.

This gives a total of twenty-seven plates completed and twenty-nine in progress, or of fifty-six plates engraved or engraving within the year.

The complete list, giving the titles of these maps and charts, is appended to the report of the assistant in charge of the office, and a general list of all that have been engraved up to the present date also accompanies it, (Appendix No. 19.) The complete list includes three hundred and eleven titles, of which sixty-eight are of first class or finished maps. The total given is exclusive of seventeen plates of progress sketches.

In the following list, containing the titles of maps, charts, and sketches which accompany this report, the letters in the margin correspond to the geographical sections, as A to Section I, B to Section II, and so on. In each section the sketches are arranged geographically, the numbers in the list corresponding to those which designate the several sheets.

1.—A. Progress sketch, Section I, (primary triangulation.)
2.— Progress sketch, Section I, (secondary triangulation, topography, and hydrography.)
3.— Nantucket shoals and sound.
4.— Martha's Vineyard sound.
5.— Entrances to Buzzard's bay and Narragansett bay.
6.—B. Progress sketch, Section II.
7.— Diagrams illustrating laws in the annual and diurnal inequality of the magnetic declination at Philadelphia.
8.—C. Progress sketch, Section III.
9.— Patuxent river, Md., (upper sheet.)
10.—D. Progress sketch, Section IV.
11.— Albemarle sound, (eastern part.)
12.— Albemarle sound, (western part.)
13.—E. Progress sketch, Section V.
14.— Ossabaw sound, Ga.
15.—F. Progress sketch, Section VI, (Florida peninsula.)
16.— Progress sketch, Section VI, (Florida reefs and keys.)
17.— St. Augustine harbor, Fla.
18.— Florida reefs and keys.
19.— Gulf Stream explorations, Sandy Hook to Charleston.
20.— Gulf Stream explorations, Florida and Tortugas.
21.— Gulf Stream chart.
22.— Gulf Stream diagrams of recent explorations.
23.— Plan of magnetic observatory at Key West.
24.— Diagrams showing results of magnetic observations at Key West.
25.—G. Progress sketch, Section VII.
26.— Santa Maria de Galvez and Escambia bays, Fla.
27.— Gulf of Mexico, deep-sea soundings.
28.—H. Progress sketch, Section VIII.
29.— Entrance and approaches of Mobile bay.
30.— Mississippi sound.
31.— Passe à Loutre, (Mississippi delta.)
32.—I. Progress sketch, Section IX.
33.—J. Progress sketch, Section X, (San Diego to San Luis Obispo.)
34.— Progress sketch, Section X, (San Luis Obispo to Bodega Head.)
35.— Drake's bay and approaches, Cal.
36.—K. Progress sketch, Section XI.
37.— General progress sketch of the Atlantic, Gulf, and Pacific coasts.

38.— Coast of Labrador, its geological structure, &c.
39.— Diagrams illustrating phenomena of the solar eclipse of July, 1860.
40.— Specimen cups for shallow soundings, and compass dividers.

At the date of my last report I had strong hopes of obtaining a more perspicuous set of progress sketches to accompany my report, but after examining many projects presented, the objections to each and every one of them seemed so much stronger than to the present sketches, that I have reluctantly been obliged to admit that for the present no change is expedient.

The use of photography in reducing maps for engraving is discussed in a separate article in this introduction.

The office estimates up to the close of the year 1861 include the drawing of seventy of the one hundred and thirteen maps and charts on the scale $\frac{1}{80000}$, and give an average progress of nearly eight of these maps each year, so that they will all be in hand as early as the field parties can furnish the material; and, in fact, if the Drawing and Photographic Divisions had merely to keep up with the current work, the force of the Drawing Division would prove too large.

ESTIMATES FOR THE FISCAL YEAR 1861–'62.

The annual estimates are precisely the same in amount as those of last year, and are stated in the usual way, the work to be executed being stated with the amount needed for its accomplishment. This scale of estimate contemplates the completion of the field-work on the Atlantic and Gulf coast in eight to ten years from the present year. By restoring it to the grade of 1857–'58, a year in time may be saved. I have conformed to the expressed policy of the Treasury Department in keeping the items at the reduced standard of last year.

The loss of the steamer Walker, by collision at sea, requires an appropriation to replace her. As the government acts as its own insurer, this is an indispensable item of estimate. The loss of a considerable part of the records of last season's work, and the loss of time from having no steamer to take the Walker's place in the Gulf of Mexico, will be sensibly felt in our progress, and I would respectfully urge that another steamer be supplied at the earliest practicable period, so as to enable us to work up again as soon as possible to the former efficiency.

The estimates suppose the same aid from the War and Navy Departments as heretofore. Should any part of this be withheld, the proportionate progress of the survey must be diminished, and its completion be postponed accordingly.

The several items now presented are the same in amount as have thrice met the approval of Congress, and once by the Congress which will pass upon these.

The item for the line across the Florida peninsula will complete that work. Twenty-seven miles were executed last season in an air line, and forty-three remain to be completed to reach Cedar keys. (See the accompanying sketch No. 15.) Allowing the usual progress this season, the next year, with the amount asked, will complete this triangulation. The saving over that which would have been required for a main triangulation around the peninsula cannot be estimated at less than four times the cost of this work across.

ESTIMATES IN DETAIL.

For general expenses of all the sections,* namely: rent, fuel, materials for drawing, engraving and printing, and ruling forms; binding; transportation of instruments, maps, and charts; for miscellaneous office expenses, and for the purchase of new instruments, books, maps, and charts $19,000

SECTION I. *Coast of Maine, New Hampshire, Massachusetts, and Rhode Island.* FIELD-WORK.—To continue the primary triangulation in this section and to make the

* Viz: of all included in this item, inclusive of Sections I to IX, and exclusive of Section VI.

astronomical and magnetic observations connected with it; to extend the secondary triangulation from *Isle au Haut* and the mouth of the *Penobscot* along the coast eastward towards *Englishman's bay*, and to continue that of *Passamaquoddy bay;* to commence the topography of *Goldsborough harbor*, of *Frenchman's bay*, and that of *Penobscot bay;* to continue that between the *Kennebec* and *Sheepscot rivers*, and that of the coast east of the *Kennebec;* to extend eastward that of *Casco bay*, and complete that of *Cape Cod bay;* to continue the in and off shore hydrography of the coast of *Maine*, including *Muscongus bay*, *Penobscot bay*, and the ledges off the coast; to continue the tidal and magnetic observations at *Eastport*, and to make tidal observations in connection with the hydrography: OFFICE-WORK,—To make the computations required by the field-work; to complete the drawing of coast maps and charts No. 7, *Muscongus bay to Portland*, and No. 11, *Plymouth to Hyannis;* to complete the engraving of coast map and chart No. 9, *Kennebunkport to Cape Ann;* charts of the *Sheepscot* and *Kennebec rivers*, and the sketches of the section; to continue the engraving of preliminary sea-coast chart No. 3, *Small Point to Cape Cod*, coast map and chart No. 10, *Ipswich to Green harbor*, the chart of *Portland harbor*, and the engraving of No. 11, the drawing and engraving of off-shore chart No. II, *Cape Ann to Gay Head*, and that of coast map and chart No. 8, *Seguin island to Kennebunkport;* to continue the drawing and commence the engraving of preliminary sea-coast chart No. 2, *Isle au Haut to Cape Elizabeth*, and drawings for charts of the *Damariscotta entrance* and *Jeffrey's bank*, will require $43,000

SECTION II. *Coast of Connecticut, New York, New Jersey, Pennsylvania, and part of Delaware.* FIELD-WORK.—To commence the triangulation of the rivers of *Connecticut;* to continue the topography of the shores of the *Hudson;* to continue the hydrography of the *Hudson river*, and, if practicable, to commence that of the rivers of *Connecticut;* to execute miscellaneous work of revision in the section and continue the tidal observations: OFFICE-WORK,—To make the requisite computations; to complete the drawing of coast map and chart No. 21, *New York bay and harbor*, (new edition,) and engrave soundings on the lower sheet of *Hudson river;* to draw and engrave hydrographic sketches of the vicinity of *Sandy Hook shoals* and *Barnegat*, and others, to show progress; and to continue the engraving of chart No. 21, will require 14,000

SECTION III. *Coast of part of Delaware and that of Maryland and part of Virginia.* FIELD-WORK.—To continue the astronomical and magnetic observations required in the section; to examine and preserve the more important triangulation stations; to continue the triangulation of the *Potomac river* in connection with its topography; to continue the topography of the *James river*, and that of the outer coast of *Virginia*, if practicable, and to complete that of the lower part of *Chesapeake bay;* to continue the off-shore hydrography of the section, the hydrography of the *Potomac river*, and the tidal observations: OFFICE-WORK,—To make the reductions and computations required; to complete the drawing and continue the engraving of the upper sheet of the *Patuxent river;* to complete the drawing and commence the engraving of the lower sheet of the *Potomac river;* to complete the engraving of chart No. 32, *Chesapeake bay*, between *Magothy and Hudson rivers;* to continue the engraving of charts Nos. 35 and 36, *Chesapeake bay*, between the entrance and *Pocomoke sound;* to continue the drawing and commence the engraving of off-shore chart No. IV, *Cape May to Currituck;* to continue the engraving of coast map and chart No. 29, between *Green River inlet and Little Machipongo*, and commence that of the chart of *James river entrance;* to

commence the drawing of coast map and chart No. 30 *bis*, between *Great Machipongo and Cape Henry*, and to draw and engrave the sketches of the section, will require $25,000

SECTION IV. *Coast of part of Virginia and part of North Carolina.* FIELD-WORK.—To continue the primary triangulation of *Pamplico sound* and the secondary in connection with it; to make the necessary magnetic observations; to complete the topography of the outer coast of *North Carolina*, south of *Hatteras*, to a junction with the *Core sound* work; to continue the in and off shore hydrography between *Cape Lookout* and *Cape Fear;* to continue observations of the tides and currents, and of the *Gulf Stream:* OFFICE-WORK,—To make computations from the field data; to complete the drawing of coast maps and charts Nos. 46 and 47, *Cape Lookout to Barren inlet*, and to draw and engrave sketches of progress in explorations of the *Gulf Stream;* to continue the drawing of off-shore chart No. VI, from *Ocracoke to Charleston harbor;* of coast map and chart No. 37, *Cape Henry to Currituck*, and that of No. 42, *Pamplico sound;* to continue the engraving of preliminary sea-coast chart No. 11, *Cape Hatteras to Cape Lookout;* to commence the drawings of coast maps and charts Nos. 38 and 39, from *Currituck to Hatteras light-house*, and No. 44, from *Hatteras light to Ocracoke inlet;* to commence the engraving of coast map and chart No. 46, *Cape Lookout to Bogue inlet*, and to engrave the sketches of the section, will require 23,000

SECTION V. *Coast of part of North Carolina and that of South Carolina and Georgia.* FIELD-WORK.—To continue the coast triangulation from the boundary of *North and South Carolina*, southward and westward towards *Winyah bay;* to extend the primary triangulation south of *Port Royal sound* towards the *Savannah river*, and make the secondary triangulation of the intervening rivers; to complete the secondary triangulation of the coast of *Georgia*, and to measure, if practicable and requisite, supplementary bases in the section; to continue the topography of *Port Royal sound*, and of the islands and interior passages between it and *St. Helena sound;* to continue that of the shores of *Wassaw sound* and of its rivers, and to join with the work on the passages from *Savannah river;* to execute the hydrography of *Wassaw sound* and its dependencies, connecting with *Tybee entrance* and *Savannah river*, and if practicable to begin that of *St. Andrew's sound;* to connect the hydrography of *Doboy entrance* with the in-shore work between *Sapelo and St. Simon's;* to run the off-shore lines required off the coast of *North and South Carolina and Georgia;* to continue the tidal observations at *Charleston* and *St. Mary's river entrance*, and to make, if practicable, tidal and current and *Gulf Stream* observations: OFFICE-WORK,—To continue the computations from field records; to complete the drawing and engraving of lines of deep-sea soundings run in this section; to continue the drawing and engraving of a chart of *Broad and Beaufort rivers, S. C.*, and the engraving of the chart of *Ossabaw sound;* to continue the drawing of off-shore chart No. VII, from *Winyah bay to St. John's river*, coast map and chart No. 54, from *Fripp's inlet to Ossabaw sound*, Nos. 56 and 57, from *St. Catharine's sound* to *St. Mary's river*, preliminary sea-coast chart No. 15, from *Savannah river* to *St. John's river*, and commence the engraving of the chart of *St. Catharine's sound, Ga.;* to commence the drawing of charts of *Wassaw and Doboy sounds;* to commence the engraving of coast map and chart No. 53, between *Stono inlet* and *Fripp's inlet*, and to engrave the sketches of progress, will require 36,000

SECTION VI. *Coast, keys, and reefs of Florida. (See estimates of appropriation for those special objects.)*

SECTION VII. *Part of the western coast of the Florida peninsula, and part of the northern coast of Florida.* FIELD-WORK.—To continue the triangulation of *St. Joseph's bay* (*south*) into Section VI; to continue that of *St. Joseph's bay*, (*north*,) and of the coast towards the work of *St. Andrew's bay;* to continue the triangulation of *Santa Rosa sound*, eastward, and continue, if practicable, that of *Perdido bay;* to make such astronomical and magnetic observations as may be practicable in the section; to continue the coast topography from *Bayport* southward; to complete that of *Crooked river*, and continue that of the shore of *St. Vincent's sound* westward towards *Cape San Blas*, and commence that of *St. Joseph's bay*, (*north;*) to continue that of *Santa Rosa sound*, and, if practicable, that of *Perdido bay;* to complete the hydrography of *St. George's sound*, and that outside of *St. George's* and *Dog islands;* to complete the soundings in the dependencies of *Pensacola bay*, and, if practicable, continue the hydrography of *St. Vincent's sound* and south of *Cedar keys;* to make the requisite tidal observations: OFFICE-WORK,—To deduce results by computations; to draw the topography and commence the engraving of coast map and chart No. 81, coast of Florida, from *Chassahowitzka river* to *Cedar keys;* to complete the drawing of No. 85, *St. George's sound*, (*eastern part*,) the engraving of the chart of *Maria de Galvez and East bays*, and the drawing and engraving of lines of deep-sea soundings in the *Gulf of Mexico;* to draw and engrave progress sketches of the section; to continue the drawing of off-shore chart No. XIII, coast of Florida, from *Waccassassa river to Choctawhatchee river*, and that of coast map and chart No. 84, Florida coast, from *Ocilla river to Crooked river*, (*St. George's sound*,) and to commence the drawing of a chart of *Crystal river offing*, will require $33,000

SECTION VIII. *Coast of Alabama, Mississippi, and part of Louisiana.* FIELD-WORK.—To continue the astronomical (including longitude) and magnetic observations required in the section; to complete the triangulation of *Isle au Breton sound*, and to commence that of the outer coast between the *Mississippi delta* and *Barataria bay;* to complete the triangulation of the *delta* and that of *Atchafalaya river*, from *Berwyck* to *Atchafalaya bay;* to commence triangulation at *Pt. au Fer* and extend it towards *Ship shoal* and *Isle Dernière;* to keep the topography up with the triangulation here enumerated, and, if practicable, to continue that of *Marsh island*, (*Côte Blanche bay;*) to continue the hydrography of *Chandeleur* and *Isle au Breton sounds*, and to complete that of the *Mississippi passes*, and that of *Côte Blanche bay*, to the limits of the triangulation; to continue the off-shore lines of soundings in the *Gulf of Mexico*,* in this section, and to make the tidal and current observations required: OFFICE-WORK,—To continue computations; to complete the drawing and engraving of the resurvey of parts of *Mobile bay*, including *Dog River bar* and the entrances of *Mobile*, *Spanish*, and *Tensaw rivers;* to continue the engraving of coast map and chart No. 100, from *Pt. au Fer to Marsh island*, and the drawing of off-shore chart No. XIV, Gulf coast, from *Choctawhatchee river to the Mississippi delta;* to continue the drawing and engraving of the chart of *Côte Blanche bay;* to commence that of the *Southwest pass of the delta*, and to complete the sketches of the section, will require 31,500

SECTION IX. *Part of the coast of Louisiana, and coast of Texas.* FIELD-WORK.—To continue the triangulation of the Gulf coast, from *East bay* eastward and northward; to continue that of *Laguna della Madre and Isla del Padre* southward towards the boundary; to continue the topography of *Nueces* and *Corpus Christi bays*, and that of the coast, southward; to continue the hydrography of the outer

* This supposes that a steam vessel has been provided to replace the steamer Walker, lost by collision at sea.

coast, from its limit above *Matagorda entrance* southward, and to complete that of *Matagorda bay* and its dependencies; to make the tidal observations required: OFFICE-WORK,—To make computations; to complete the drawing and continue the engraving of coast map and chart No. 108, *Matagorda and Lavacca bays;* to complete the topographical drawing of No. 109, Gulf coast, from *Matagorda to Aransas Pass*, and the engraving of Nos. 106 and 107, between *Galveston and Matagorda entrances;* to continue the drawing of off-shore chart No. XVI, Gulf coast, from *Galveston to the Rio Grande;* to draw and engrave the sketches of the section, and to commence the engraving of coast map and chart No. 105, *Galveston bay and approaches*, will require $25,500

Total for the Atlantic coast and Gulf of Mexico 250,000

The estimates for the Florida coast, keys, and reefs, and for the western coast of the United States, are intended to provide for the following progress:

SECTION VI. *Coast, keys, and reefs of Florida.* FIELD-WORK.—To continue the triangulation of the eastern coast of the Florida peninsula, from *Halifax river* southward, and that of *Indian river* and the adjacent coast northward; to commence, if practicable, that from *Cape Florida* northward; to complete the triangulation of the keys and coast between *Florida bay* and *Card's sound;* to complete that of *Sarasota sound*, and to commence that of *Tampa bay;* to follow the triangulation of *Halifax river* and the coast adjacent with the topography, and continue that of *Indian river* and the neighboring coast; to complete the topography of the southern keys and coast of the peninsula, from *Barnes's sound* to the work at *Cape Sable;* to follow the triangulation of *Sarasota* and *Tampa bays* by the topography; to extend, if practicable, the in-shore hydrography north and south of *St. Augustine;* to continue the hydrography of *Florida bay*, and to run off-shore lines from the reefs and coast of this section; to complete the hydrography of *Charlotte harbor* and its approaches, and to keep up the tidal observations at the *Tortugas:* OFFICE-WORK,—To compute results from field records; to complete the drawing and continue the engraving of off-shore chart No. X, *Florida reefs and keys*, from *Key Biscayne* to *Cape Sable;* to complete the engraving of *St. Augustine harbor and approaches*, that of coast map and chart No. 71, *Florida reefs*, between *Newfound Harbor key* and *Boca Grande*, and the drawing and engraving of the sketches of progress; to complete the engraving of topography on the chart of *Charlotte harbor*, continue the drawing of coast maps and charts Nos. 69 and 70, *Florida reefs, from Garden key to Newfound Harbor key*, and No. 74, *Florida reefs*, from *Lower Matecumbe key* to *Cape Sable*, and to commence the drawing of coast map and chart No. 64, *Florida coast*, between *Jupiter inlet* and *Indian River inlet*, will require $40,000

SECTION X. *Coast of California.* FIELD-WORK.—To continue the triangulation from the *Santa Barbara* base northward, and to complete that of the islands off *Santa Barbara channel;* to continue the primary and secondary triangulation north and south from the *San Francisco* base, and to make reconnaissances for extending this work; to make the astronomical and magnetic observations in connection with the triangulation; to continue the topography of the shores of *Santa Barbara channel* and of the islands off the coast; to continue the topography south of *Monterey bay* and that of *Bodega* and *Tomales bays;* to continue the hydrography (in-shore and off-shore) north and south of *San Francisco entrance*, and that of *Santa Barbara channel*, with such other hydrographic work as the progress of the survey may show to be first needed; to continue the tidal observations in the

section: OFFICE-WORK,—To continue the computations and reductions of the field-work; to complete the drawing and engraving of charts of the vicinity of *Santa Cruz*, *Santa Rosa*, and *San Nicolas islands*, (Santa Barbara channel;) to complete maps of *Petaluma* and *Napa creeks*, *San Pablo bay*, and the sketches of the section, and to continue the drawing of the chart of the coast north of *San Francisco entrance*, including *Drake's bay*. Also for the operations in—

SECTION XI. *Coast of Oregon and that of Washington Territory.* FIELD-WORK.—To continue the triangulation of *Washington and Puget's sounds* and of *Hood's canal*, and the topography and hydrography connected with it; to complete the hydrography of the *Gulf of Georgia*, and to execute such other hydrography as the progress of the survey may show to be first required; to continue the tidal observations in this section: OFFICE-WORK,—To continue the drawing and commence the engraving of a chart of *Washington sound;* to commence the drawing of a chart of the *Gulf of Georgia*, and to complete the charts of *Coquille River entrance* and *Gray's harbor*, and the sketches, will require $130,000

The other items of appropriations asked are precisely the same in amount as last year. The terms of that for the line across the Florida peninsula express that it is the last appropriation which will be required for that object.

For completing the line to connect the triangulation on the Atlantic coast with that on the Gulf of Mexico, across the Florida peninsula, per act of March 3, 1843.... 5,000

For publishing the observations made in the progress of the survey of the coast of the United States, per act of March 3, 1843.............................. 5,000

For repairs of steamers and sailing schooners used in the survey, per act of March 2, 1853 10,000

For fuel and quarters and for mileage or transportation for officers and soldiers of the army serving in the Coast Survey, in cases no longer provided for by the Quartermaster's department, per act of August 31, 1852.................... 5,000

For pay and rations of engineers for seven steamers used in the hydrography of the Coast Survey, no longer supplied by the Navy Department 12,800

The amounts thus estimated for the work of the fiscal year 1861–'62, and the appropriations for the present year, are given in parallel columns:

Object.	Fiscal year 1861–'62.	Fiscal year 1860–'61.
	Estimated.	*Appropriated.*
For survey of the Atlantic and Gulf coasts of the United States, including compensation of civilians engaged in the work, per act of March 3, 1843	$250,000 00	$250,000 00
For continuing the survey of the western coast of the United States, including compensation of civilians engaged in the work, per act of September 30, 1850	130,000 00	130,000 00
For continuing the survey of the Florida reefs and keys, including compensation of civilians engaged in the work, per act of March 3, 1849	40,000 00	40,000 00
For completing the line to connect the triangulation on the Atlantic coast with that on the Gulf of Mexico, across the Florida peninsula, including compensation of civilians engaged in the work, per act of March 3, 1843	5,000 00	5,000 00
For publishing the observations made in the progress of the survey of the coast of the United States, including compensation of civilians engaged in the work, per act of March 3, 1843	5,000 00	5,000 00
For repairs of steamers and sailing schooners used in the survey, per act of March 2, 1853	10,000 00	10,000 00
For fuel and quarters, and for mileage or transportation for officers and enlisted soldiers of the army serving in the Coast Survey, in cases no longer provided for by the Quartermaster's department, per act of August 31, 1852	*5,000 00	5,000 00
For pay and rations of engineers for seven steamers used in the hydrography of the Coast Survey, no longer supplied by the Navy Department	†12,800 00	12,800 00

* Formerly included in estimates of the War Department. † Formerly included in estimates of the Navy Department.

These are the regular items of annual expenditure. The loss of the steamer Walker requires, to restore the efficiency of the hydrography, the following, which forms no part of the annual expenditure of the survey:

To provide for a steam vessel in place of the steamer Walker, lost by collision at sea, $45,000.

This last item can only be considered as replacing part of the capital of the survey, for which the government has been the insurer.

DEVELOPMENTS AND DISCOVERIES.

The general list up to 1859, inclusive, is given in Appendix No. 8, to which are also added, in the same form, the special developments made within the present year. The list includes one hundred and seventy-four items geographically arranged.

While these developments are among the most palpable advantages of the Coast Survey, the special statements in regard to them are only a part of the general facts shown on the maps and charts.

I am again indebted to George W. Blunt, esq., of New York, in having received from him a notice by Captain Lott, of the steamship Asia, of a rip with eleven fathoms, and with considerably deeper water around it, about fourteen miles south of Fishing Rip, and twenty-four miles southeast of Davis's shoal. As it did not appear that this space was sounded out by Lieut. Comg. McBlair, or Commander Stellwagen, U. S. N., who furnished the hydrography of the vicinity of the Nantucket shoals, I detailed a party at once for this work, and the development has been made which is briefly referred to here, and more particularly under the head of Hydrography of Section I. In prosecuting that service, Lieut. Comg. Phelps discovered in the same vicinity a much more extensive shoal, commencing half a mile eastward of the rip, and stretching N.NE. more than six nautical miles, with ten to ten and a half fathoms on it. This shoal is separated by deep water from the rip referred to.

The resurvey of parts of Boston harbor to develop the changes and their causes has been made at the expense of the city, and has led to results of importance to the future of that great commercial centre.

I append here a list of the special localities in which developments have been made by the hydrographic or other parties during the present season.

1. A ledge with four fathoms water on it, discovered S.SW. ¼ W., (true,) and a mile and a quarter from Pemaquid light-house, coast of Maine.
2. Numerous dangerous reefs and ledges developed at the entrance and in the approaches of Damariscotta river, Me.
3. Two rocks, one with three and a quarter fathoms, the other with only ten feet of water, and a ledge with three and a half fathoms found in the channel of Booth bay, Me.
4. Jeffrey's bank and Jeffrey's ledge. off the coast of Maine, thoroughly sounded out.
5. Determination of the position of White Rock ledge at the entrance of Saugus river, Mass.
6. Discovery of a rock with only seventeen feet of water at mean low tide in the Narrows of Boston harbor.
7. Special investigation of the currents of Boston harbor.
8. Special tidal and current observations at the mouth of Scusset river, (Cape Cod bay.)
9. Discovery of a shoal lying N.NE. over six miles long, and twenty-four miles southeast of Davis's south shoal, with ten to ten and a half fathoms of water.
10. Extent of the sea encroachment at Cape Hatteras, and changes found near Hatteras inlet, N. C.
11. Greater depth found through the channel of Coosaw river, S. C., (inland passage,) than has been hitherto supposed to exist.

12. Changes in shore-line and in depth observed in Ossabaw sound, Ga.

13. A new channel developed leading into Sapelo sound, Ga., three quarters of a mile southward of, and better than the one in use.

14. A shoal spot found off the coast of Florida, ten miles from land, and fifteen miles NE. of Indian River inlet.

15. Tennessee shoals, Florida reef, developed, giving only twelve feet of water on the outer shoal.

16. The position of a sunken wreck determined and marked, lying off Grassy key, Florida reef, and near the track of vessels.

17. Further investigation of the character of the Gulf Stream in the Florida straits.

18. Indications noticed of a deeper and better channel forming, to lead to the East Pass anchorage, St. George's sound, Fla.

19. Changes in the depth of water observed by comparison of soundings at Perdido entrance.

20. The currents of Mobile bay specially investigated.

SPECIAL SURVEYS.

These have been three in number, undertaken by request and at the expense of the parties named, and with the approval of the Treasury Department. In the order of time at which they were undertaken they are: of Mobile bay, to ascertain the changes and present condition of the bay, undertaken at the request and expense of the commissioners on the improvement of Mobile harbor and bay, named in a law of the State of Alabama; of Boston harbor, undertaken by request and at the expense of the city government, and of the site of a proposed canal to connect Buzzard's and Cape Cod bays so as to avoid the dangerous coasting navigation around Cape Cod peninsula and by the inner Nantucket shoals, at the request of a committee of the Massachusetts legislature and at the expense of the State. These surveys all furnish important data for the direct purposes of the Coast Survey, besides rendering great service to the commerce and navigation of important localities, and of the country generally. They find their precedent in the elaborate works in Portland, New York, and Charleston harbors, undertaken by city and State action. They are connected, as in these cases, with the action of commissioners on those harbors, or of advisory councils of officers connected with the United States government, of which the Superintendent of the Coast Survey is a member. The preservation of the harbors of the country is the object, by preventing dangerous encroachments on the water in the rapid progress of buildings and of improvements on land, by ascertaining the changes caused in the water space by the changes in the land, and the causes of these changes. More elaborate observations of tides and currents, of hydrographic, and sometimes of topographical details, are needed than are demanded for purposes of navigation, and hence beyond the usual requirements of the Coast Survey, and properly at the expense of the local authorities.

The detailed statement of the several parts of these surveys will be found under their appropriate heads in Sections VIII and I. I propose now merely to state some of the leading observations made, and of the general results arrived at.

In Mobile bay, besides the usual soundings which were minutely made at the head of the bay, and in the rivers forming the delta of the Alabama river, numerous current stations were occupied at which the direction and force of the currents were observed at the surface and at various depths below it. These were selected with the view to determine the causes of change which the hydrography developed, and to ascertain the direction in which changes might still be expected; also the greater or less scour of tidal and river currents at different places and depths, and under different circumstances. The results are represented on elaborate diagrams,

which address the eye immediately, permitting a ready and rapid generalization of the facts. The current observations were connected with those on the tides at stations suitably selected.

In the course of the tidal and current observations off the bar, at the entrance to the bay, it was discovered that there is a general current setting from the eastward, modifying the direction and force of both ebb and flood tidal currents which tend out of and into this great bay, and determining the final direction of its channel and bars. This is an important fact for future development.

The tables resulting from the observations furnish the data for tracing the currents of the rivers into the bay, and of the bay into the ocean, in direction and velocity, at and below the surface, in the channels and passes, upon the bars, and in the bay and gulf; the effects of winds; the direction and force of the scouring forces furnished by the currents in the different strata of water from the surface to the bottom, giving to the engineer a clue to guide him in the labyrinth of effects—now a pool, now a shallow, now a channel, now a bar.

The case of Boston harbor is a very different one; small rivers only enter its head, while the ocean tide rises to a six-fold height, and their currents are divided by numerous islands which they abrade, and which are exposed to the violence of the waves of a habitually stormy sea. The old tidal reservoirs which gave scour have been, in many cases, partially filled up or obstructed in the progress of improvement, and changes of regimen of considerable importance have been produced. A comparison of the old and new maps show this. The same officers who worked in Mobile bay, Lieut. Comg. J. Wilkinson and Assistant Henry Mitchell, have given their attention to the developments here. The inner harbor has been sounded out to compare with the results of Commander Charles H. Davis, who made the survey in connection with the Coast Survey in 1852, and with the earlier results of Commodore Wadsworth. Parts of the main ship channel have been re-examined. Assistant Mitchell has occupied current stations at the approaches in the main ship channel, and the various passages among the islands in the inner harbor, and at the entrance to its affluents, the Charles and Mystic rivers, and Great South bay. He has examined the causes of the most important shoals, flats, and spits where changes have occurred or are occurring, with a view to present such results to the commissioners as may enable them to suggest the measures needed to prevent the deterioration of this important harbor. To show the nature of the results obtainable from such observations, I quote a few lines from Assistant Mitchell's report. "At this station we determined that the flats off South Boston may be the deposit both of suspended and rolled materials, since the ebb from the rivers above (the Charles and Mystic) sets over upon them, and the resultant of all the forces of the currents for twenty-five hours takes a course towards the boldest place, (S. 4° W.) The portion of the shoal towards which the ebb sets is found to be a place of no activity of current, so that whatever is carried there lodges in the long grass. The set of the resultant in the same direction shows the origin of the sandy strata of the flats." I shall, at a future time, present the details of Assistant Mitchell's ingenious and persevering investigations in the Appendix to my report, when the subject is matured by him.

In the connection with this work of his, I should refer to the ingenious instruments devised for bringing up specimens of the materials of shoals, &c., at different depths, described in Appendix No. 39.

Resurveys of the principal islands have been made on a large scale, and with all the resources of topographical execution for which he is so distinguished, by Assistant H. L. Whiting, of the Coast Survey; and the maps have been furnished to the commissioners, to show, by comparison with former Coast Survey work, the wearing away of the islands, and the formation of spits, beaches, and the like.

TIDE TABLES.

These have undergone a revision in the Tidal Division of the Coast Survey office, and a tide table for Key West, where the diurnal inequality is considerable, has been added on the

same plan as that adopted for the Pacific coast, where the tides are of a similar type with these. The Key West tides are the representation of those along the Florida coast to Cape Florida, where the large diurnal inequality is much diminished, and the tides take the Atlantic form. Also of those along the western coast of the Florida peninsula to Cape San Blas. The same type is slightly shown between Isle Dernière, on the coast of Louisiana, and Galveston, on the coast of Texas.

The tables in the Appendix No. 16 give the corrected establishment or mean lunitidal interval of one hundred and ten ports, the rise and fall of mean, spring, and neap tides, and the mean duration of the flood and ebb tide and of the stand between them. Rules are given which enable the navigator to compute the time and height of high and low water, and to correct the rough computations, if he chooses to go into details, for half monthly and daily inequality. The tides of the Atlantic, Gulf, and Pacific coasts are treated, and easy rules given in relation to tidal currents of the Atlantic coast. These tables are continually corrected from the observations made at the permanent tidal stations, and chiefly with self-registering instruments for both time and height. The results are regularly transmitted to the office and there computed.

TIDES AND CURRENTS.

The permanent tidal stations on the Atlantic, Gulf, and Pacific have been kept up as heretofore, six on the Atlantic coast, three on the Pacific, and two on the Gulf of Mexico.—(See Appendix No. 18.) Two improvements in the self-registering gauges are noticed in the report of Assistant Pourtales, in charge of the Tidal Division, one a method of keeping the gauge from freezing during the winter season by the use of kerosene oil, and the other a contrivance for equalizing the action of the weight on the receiving and delivering rollers of the gauge, as the paper accumulates in one and is wound off the other. Through the kindness of Lieut. Dahlgren, U. S. N., the tide-gauge at the Washington navy yard is kept up. The observations along the western coast of the Florida peninsula having been kept up for a year, the gauges have been transferred to parts further westward, between St. Mark's and Last island, on the coast of Louisiana. The change of type of the tidal curve from the semi-diurnal, with a large inequality, into the diurnal type, which occurs between St. Mark's and Cape San Blas, is very gradual, as has been found by intermediate stations at Dog island and Cape St. George, coast of Florida. The observations in the Pensacola navy yard have been kept up by S. Thayer Abert, esq., engineer of the yard. Meteorological observations have been kept up in connection with the tidal ones.

The current observations in Mobile bay, Boston harbor, and Buzzard's and Cape Cod bays are relative to special surveys, under which head they will be noticed.

RULES FOR PHOTOGRAPHING, DRAWING, AND ENGRAVING OF MAPS, CHARTS, ETC.

In 1845, and the years immediately following, the subject of the style of drawing and engraving the maps and charts of the survey was discussed in great detail by Captain A. A. Humphreys, then assistant in charge of the Coast Survey office, and by Assistants John Farley and W. M. C. Fairfax and myself, with the aid of Messrs. Selmar Siebert, F. Dankworth, and John Knight, engravers. Great pains were taken in that early stage of the work to introduce uniformity and system in the execution of the various kinds of office-work. In the numerous changes of officers in charge of the office and its divisions many departures had occurred from this system. Besides, large numbers of maps and charts of different orders had been published, and the criticisms upon them by navigators and others had enlightened us on many doubtful points. The labor, too, of engraving the first class charts in the style adopted had, under the most favorable circumstances, proved greater than was expected. But above and before all other reasons, photography was to be introduced as a regular part of office detail, and great changes were necessarily consequent. I determined therefore to have a thorough

revision of the whole system; to re-establish approved rules and usages, and carefully to study new ones; to avail ourselves, in short, of the experience acquired in the field and office for a new step in improvement. Assistant H. L Whiting, whose experience in field topography is greater than that of any other assistant in the survey, and whose success in all matters relating to representations of ground in the field and office is very great, was ordered to the office to study the whole subject. His communications with me, with the assistant in charge, the chiefs of the Drawing and Engraving Divisions, and with Mr. Mathiot, the draughtsmen, and the engravers, were constant, and subject after subject was passed in review by him, and all the experience and knowledge at hand were brought to bear upon the conclusions. As the subjects were matured and met my approval, they were embodied in a series of office directions, to be carefully observed by all concerned.

It would lead to too much technical detail to give here the discussions of the subjects or the rules and directions adopted, but in justice to the labors thus accomplished I must briefly allude to the different matters embraced in Assistant Whiting's reports, and which were definitively settled for the present by office rules.

The whole subject of topographical and hydrographic reductions was reviewed; the constituent parts of the map or chart; the representation of natural and artificial objects; the conventional signs; the lettering; and the figures, as especially adapted to the coast maps and charts on the scale of $\frac{1}{80000}$, and those coming under the same rules.

The subject of the scale of shade, by which ground is represented by hachures, was carefully gone over. The scale of Lehman and that of natural sines had been critically examined, in 1845, by Captain Humphreys and Assistant Fairfax, and a modified scale had been adopted which represented more distinctly the smaller slopes from 0° to 5°, and the higher slopes, at which Lehman's scale also fails to give distinctions. This scale of shade not only secures variety and picturesque effect in the maps, but, if thoroughly carried out, enables an expert to infer each slope accurately from the hachuring. The modifications introduced by the study of Mr. Whiting, aided by the researches of Mr. Mathiot, and the trials of Mr. E. Hergesheimer, are briefly stated in Mr. Whiting's report, as follows: "The new scale proposed is based upon the strong and effective line of Lehman, from 5° to 25°, (its best section,) and from 25° to 40° it follows the line or curve of natural sines. This gives at 5° a proportion of one part of black to eight of white, and at 40° four parts of black to one of white. Within this range the scale has been found to answer all practical demands in representing natural contour, and is considered the best gradation of light and shade which experiment could develop. Beyond these well known and mathematical bases the scale is extended in the higher range to 75°, and in the lower range to 1°. This has been done by continuing the same strength of line as at 5°, with an increase of twenty-five per cent. of white for each degree from 4° to 1°, inclusive, which gives a distinct yet pleasing contrast between these important slopes. In the higher range the unit of black is increased twenty-five per cent. for the first 5°, and twenty-five per cent. each for the next three divisions of 10°, leaving the last 15° of slope, from 75° to 90°, in full black."

This scale is at once practicable in execution and graphic in effect, and adheres with sufficient closeness to that of the existing maps, avoiding some practical difficulties which experience had developed in representing the lowest and highest slopes.

The lettering, which had originally been studied with care by Assistant Farley, aided by Mr. F. Dankworth and Mr. John Knight, engravers, was reviewed, and examples selected of the most approved in each class. The conventional signs in the topographical maps were improved; and also in the hydrographic charts, with the aid of the officers in the hydrographic division, the tendency being to simplification. New gauges for the size of figures were adopted, the former having, by general consent, been proved too small.

It will be readily understood how photography requires an entire change of system in

reducing maps and charts. Distances on the field scale of $\frac{1}{10000}$, which are considerable quantities, are insignificant, and even disappear when reduced to the scale of $\frac{1}{80000}$, so that the outlines of two buildings, for example, distinctly separated on the surveying scale, when reduced in strict proportion, coalesce, and the buildings themselves appear as mere black dots. The importance to accuracy of retaining the large scale for surveying is too great to permit that to be given up. The very object of a large surveying scale is to insure such accuracy that small aberrations will not be note-worthy on the reduced scales. Besides, the same region of country is represented on several different scales in the reduced charts adapted to in-shore and off-shore navigation, or to harbor purposes. Experience has shown that these maps are also much sought and very useful as a general guide in improvement, often of the most important and widely useful kind.

Again, photography copying faithfully on the reduced scale gives a perfect fac simile of a drawing, exhibiting minutely the style of the original. It is chimerical to suppose that any number of rules or amount of training will ever produce field drawings identical in style. It is with a man's drawing as with his handwriting; one drawing may be very like in style to another, as one handwriting is like another, and the faithful photograph represents the individuality of each style. A photographic reduction, then, from drawings by several persons would represent various styles, and, reducing every part of the drawing proportionately, would blend all of a certain degree of fineness so that the unassisted eye could not separate or distinguish them.

The difficulties usually supposed to apply to the reduction of maps by photography, distortion, shrinkage, and the like, are not the most formidable ones, but have been overcome for some time. In bringing this art into regular use we studied what was wanted on the reduced scale of the map, and how it was to be procured. From this resulted a system of generalizing, easily applied to tracings, and embracing in the cases of contours the omission of the minor irregularities of the curves; in the case of shore-lines of the minor indentations and inflections, and so on. In the case of conventional signs the exaggeration of the dimensions of objects to be shown singly, (as single houses and the like,) and the grouping of those to be represented in masses, (as villages, towns, and cities,) complete the generalization for practical purposes. These tracings occupy but little time, and the generalizations are made according to rules completed for the $\frac{1}{80000}$ scale of our coast maps and charts. As the photographic system supersedes the elaborate and elegant drawing of the former drawing school, coloring is introduced to show varieties in cultivation, wood, marsh, and the like. The generalization is made on a tracing on the full field scale. It is reduced one-fourth and studied, correcting any imperfections before they are so far reduced as to make them difficult of detection. Then reducing one-half again, coloring the reduced photograph, and sharpening such of the details as need it, completes the engraver's pictorial copy. The photographic reduction is also made on glass, so that the distances may be measured, and the outlines taken, free from the expansion of paper.

The modifications in the details of engraving formerly arranged by Capt. Humphreys, Assistant Farley, Messrs. Siebert and Dankworth, and myself, flow naturally out of these changes, and have employed the ingenuity of Messrs. Whiting, Hergesheimer, Mathiot, McCoy, Rolle, John Knight, and Mr. Hinkle, to whose interest in the matter the work is much indebted.

Assistant Whiting's reports on the interesting subjects of topographical contour and features, on hydrographic reductions and details, on photography, and on the scale of shades, are given at length in Appendix No. 20.

GEOGRAPHICAL POSITIONS, TABLE OF DEPTHS, ETC.

The table of depths and list of geographical positions are given biennially, and accompanied my last annual report as Appendix No. 15 and Appendix No. 20.

The lists of topographical and hydrographic sheets will be extended according to the number received, and given every third year or oftener. Up to the year 1859, the lists containing the titles of sheets received during the two years previous to the date of my report were given in the Appendix Nos. 18 and 19.

INFORMATION FURNISHED.

The information furnished from the archives, under the authority of the Treasury Department, during the past year, is stated in Appendix No. 6. The rule which requires from publishers of maps and charts that acknowledgment should be made on the face of the publication for the information derived from the archives is plain, and consistent with fair dealing, and the department exacts its precise fulfilment, so that the Coast Survey shall not be made responsible for more, nor receive credit for less, than the precise work communicated.

STATISTICS.

The table of statistics has been added to, so as to bring it up to the opening of the present surveying year, and is given in Appendix No. 7.

Up to 1859, inclusive, the triangulation had covered an area of nearly forty-eight thousand square miles; had developed a general extent of coast of over four thousand, and a shore-line of about twenty thousand miles, determining upwards of eight thousand geographical positions.

For longitude determinations, seventy-six stations had been occupied; for latitude, one hundred and nineteen; and for azimuth, seventy-seven stations.

The topography had extended over an area of fifteen thousand six hundred square miles, having a general coast-line of over thirty-two hundred, and more than thirty-eight thousand miles of shore-line, measuring the indentations.

The hydrography extended over an area estimated at forty-four thousand square miles, in which more than one hundred and eighty-four thousand miles were run in sounding; five million eight hundred thousand soundings made, and over eight thousand specimens of the bottom obtained.

The number of manuscript maps and charts was one thousand nine hundred and eighty-five, and of engraved maps, charts, and sketches, four hundred and forty-five plates.

DISTRIBUTION OF REPORTS AND MAPS.

The lists for the distribution of reports from the Coast Survey office have been thoroughly revised within the past year. There are now upon it over four thousand names of institutions and individuals. The demands for the report of 1858, of which a very limited edition was published, (seven thousand nine hundred and fifty copies,) have been very embarrassing, as it was impossible to supply the number of copies required. Of the report of 1859 six thousand and two hundred extra copies were ordered by the Senate, and five thousand by the House of Representatives, of which eight thousand were to be distributed from the office. The report for 1858 was published on the 1st of February, 1860, and that for 1859, it is expected, will be ready early in the session of Congress.

More than six thousand copies of maps, charts, and sketches have been distributed from the office since the date of my last report, to institutions and individuals in all parts of the United States, and through the agency of the Smithsonian Institution to those in foreign countries.

RECORDS AND RESULTS.

I must again call attention to the fact that the appropriation for the records and results merely enables us to prepare the materials from observations for publication, and not actually to publish. I would earnestly recommend that a sufficient amount be appropriated to enable us to make these publications while the results are fresh; but having dwelt upon this matter often, and shown it in its different points of view, it would be mere repetition to go again over

the subject. A volume of the Gulf Stream results is nearly ready in manuscript, and will be published if the balance with the disbursing agent of the Coast Survey permits.

LABRADOR EXPEDITION, ETC.

The subject of longitudes has been repeatedly referred to the Coast Survey by law, and every method known to science has been applied in the determinations required to connect our longitudes with those of "well determined European observatories." The astronomical and chronometric methods have been carefully applied, the former continuously, and we were prepared to use the telegraphic wire to Europe.

The total eclipse of July 18 afforded one of the best opportunities for longitude determinations and for corrections of the tables, as the central shadow passing across Washington Territory into the British dominions, and leaving the coast of North America near the northeastern part of Labrador, near Cape Chudleigh, crossed the southwestern portion of Europe in very accessible portions of Spain. The European expeditions announced were to include the leading astronomers of many countries, and it was a rare opportunity for us to co-operate in these world-wide observations. The interest excited by it in many of our statesmen is shown by the history of the legislation. A resolution (Appendix No. 21) was offered in the Senate of the United States, by the Hon. James A. Pearce, of Maryland, on the 8th of May, referred to the Library Committee, reported to the Senate, and adopted by a large vote on the same day. The resolution was moved in the House of Representatives as a report from the Library Committee, by the Hon. John U. Pettit, of Indiana, on the 12th of May, and adopted by a large vote on the 12th of June. The joint resolution thus passed was approved by the President of the United States on the 15th of June.

As directed, I proceeded to organize the expedition, assigning the Coast Survey steamer Bibb, Lieut. Comg. Alexander Murray, U. S. N., to the service, and placing it under the charge of Stephen Alexander, LL.D., of the College of New Jersey—one of the most experienced astronomers in this speciality in the United States; associating with him, under the terms of the law, four astronomers, viz: President F. A. P. Barnard, of the University of Mississippi; Professor Venable, of the College of South Carolina; Professor A. W. Smith, U. S. N., of the Naval Academy of Annapolis, and Lieut. E. D. Ashe, R. N., director of the observatory at Quebec—all volunteers in this interesting scientific enterprise. As assistants were added: for astronomy, William Henry, esq., of Washington; for meteorology, Oscar M. Lieber, esq., geologist, of South Carolina; Edward Goodfellow, assistant in the Coast Survey, and Samuel Walker, aid, for magnetic observations; Mr. Duchochois, of New York, volunteered to go as photographer to the expedition, and Mr. A. W. Thompson, aid in the Coast Survey, was assigned as his assistant.

Through the liberality of the following named individuals and institutions, the sum of eleven hundred dollars was placed at my disposal for the personal and scientific expenses of the expedition: the Smithsonian Institution, of Washington; Columbia College, New York; J. Lennox, esq., and Lorillard Spencer, esq., of New York, and Doctor Thomas B. Wilson, of Newark, Delaware. The Photographical Society of New York, through their president, Doctor Draper, interested themselves in supplying a volunteer for this service, and L. M. Rutherford, esq., liberally provided the outfit of apparatus and instruments, and gave the benefit of his experience and of his observatory in the preparations for photographing the sun.

With great zeal Lieut. Comg. Murray and his officers prepared their little steamer for this distant, arduous, and somewhat dangerous service, and she left New York on the 28th of June, arriving at Sydney, Cape Breton, where she took in a supply of coal, on the 3d of July, and at Aulezavik, in latitude 59° 47′ 49″ N., and longitude 4*h.* 16*m.* 53*s.* W., on the 13th.

I had previously communicated personally with Professor Alexander, and given written memoranda after our conference, which he was to discuss with his colleagues, in conjunction

with whom the details of arrangement were to be finally determined. The officers of the vessel were associated with the party as aids, and hydrographic instructions were given to Lieut. Comg. Murray. All these matters were fully, carefully, and satisfactorily attended to by Professor Alexander, so that on arriving at their haven of Aulezavik each one knew what was to be his contribution to the general movement.

The manner in which this was accomplished, the proceedings of the expedition on the voyage and on their arrival at Aulezavik, the preparations for the observations, the observations themselves and their results, and the return of the expedition, are all lucidly stated by Professor Alexander in his report, (Appendix No. 21,) which, with extraordinary promptness, was handed to me, with all the sub-reports, on the arrival of the steamer Bibb in the harbor of Newport, on the 7th of August. The American Association for the Advancement of Science was in session at that time in Newport, and received the returning astronomers with hearty greetings, and their statement of the results obtained, with much interest. Their return was the more opportune that, as Professor Alexander had been the president of the meeting of last year, an address from him was therefore due, and President Barnard was the president elect for the next year of the association.

The successful carrying of this expedition to the point desired, and its safe return, were subjects of congratulation to all, and reflect the highest credit upon Lieut. Comg. Murray and his officers. To the cordial co-operation of all the members of the expedition the success which attended their efforts was greatly due.

The report of Professor Alexander, and the sub-reports joined to it in the Appendix, (No. 21,) give all desirable details in reference to the scientific proceedings and results. The determination of latitude and longitude of the elevation, &c., of the station; of the magnetic declination, dip, and intensity; the distribution of labor before, on, and after the eclipse day, (the 18th of July;) the instruments used; their mounting; the character of the weather; a detailed synopsis of the observations made, including those of the times and physical phenomena; the photographic results, are all fully stated. The sub-reports on meteorological observations, by Professor Venable and Mr. Lieber; on magnetic observations, by Mr. Goodfellow and Mr. Walker; of Doctor Barnard, Lieutenant Ashe, R. N., Professor Smith, U. S. N., Professor Venable, and Mr. Lieber, on the physical and other phenemena observed by them during the eclipse; of Mr. Duchochois and Mr. Thompson, on the photographic methods and results; of Messrs. Platt, Nones, and the seamen of the steamer; and of Surgeon's Steward Collins, which accompany Professor Alexander's statement, complete the details of the account of the labors of the party.

It was a gratifying result of the foresight with which matters had been arranged, that though the astronomers were deprived of the sight of the corona by the interposition of clouds, it was seen and well observed on ship-board by the petty officers and seamen who had been assigned their part in the observing. Professor Alexander mentions with special approval the services of Engineer French and of Acting Sailing-master Platt, of the steamer. A brief but interesting report on the geology of the region visited, with a map, and of the hydrography, with maps and sketches, have been more recently forwarded by Oscar M. Lieber, esq., and Lieut. Comg. Alexander Murray, respectively.

It would be out of place here to dwell upon the results which are thus fully developed by the officers of the expedition. The report is of very moderate dimensions, and will thoroughly repay a careful perusal. The observations of the time of the several phases will be referred to the Computing Division for its use.

In complying with the terms of the joint resolution of Congress, the whole expense to the government of this expedition, over and above the ordinary expenditure of keeping the party together, was for the coal used, engineer stores, and incidental repairs to the hull of the vessel, amounting to less than two thousand dollars. The scientific expenditure was borne from the contribution fund.

Thirteen photographs of the eclipse, and thirty-six stereoscopic views of the coast of Labrador and of the doings of the party, were made by Mr. Duchochois, and are deposited in the archives of the Coast Survey.

Through the kind and intelligent interest of Sir Alexander Bannerman, governor of Newfoundland, and Sir George Simpson, of the Hudson's Bay Company, the party in the steamer Bibb were provided with such credentials as would have secured, in case of need, the sympathy and assistance of the officials connected with their respective departments on the coast of Labrador. The friendly letter of the governor of Newfoundland, advising me in regard to his action in the premises, expresses good wishes that must have been prompted by a full appreciation of the importance of the object in view.

In Appendix No. 41 will be found a statement of the particulars of the expedition to the coast of Labradór, in the form of a report from Lieut. Comg. Murray, who was in charge of the steamer Bibb.

The solar eclipse of July was successfully observed at a station near Fort Steilacoom, Washington Territory, by Lieutenant J. M. Gilliss, U. S. N., who was assigned to the Coast Survey for that purpose, on his volunteering for the service, by the honorable Secretary of the Navy. The report of Lieutenant Gilliss, and many results of interest, with the particulars of the undertaking, are given in Appendix No. 22, and alluded to under the head of Section XI.

OCCULTATIONS OF PLEIADES, ETC.

During the year the charts of predictions of occultations of the Pleiades have been forwarded, in pursuance of the general plan proposed by Professor Peirce, of Cambridge, Mass., and committed to his execution, and one hundred and thirteen results have been received from observatories and stations in the United States and in Europe. The computations have been made as heretofore, by Mr. Edward Pearce, jr., under the general direction of Professor Peirce.

The list now embraces twenty-eight stations in America, and a like number in Europe.

Charts for the series of October 14 and December 8, 1859, and of January 4, February 28, June 16, and September 6, 1860, were forwarded to the foreign stations, and records of the observations of the series of December 8, February 28, and September 6, have been received. To the American stations charts for the series of October 14, 1859, and January 4, March 26, July 13, September 6, and October 3, 1860, were sent; and of the first four the returns have been received at the office.

At the Coast Survey station on Gunstock mountain, New Hampshire, occupied by my party this season, the occultations of the 13th of July were observed, and the times of immersion and emersion of four stars of the Pleiades group carefully noted. Valuable series of observations at this epoch, within four days of the solar eclipse, were also obtained at the U. S. Military Academy, West Point; at Southwick, Mass.; and under somewhat less favorable circumstances, by Professor Göbel, at Newport, Mo.

Observations also of the occultation of the planet Venus by the moon on the 24th of April, and of two stars on the 5th of March, have been communicated; the first by Professor W. B. Jack, of Fredericton, N. B.; and those of the second date by J. Hartnup, esq., of the Liverpool Observatory, England.

The records of forty-two moon culminations observed at Cincinnati have been furnished by Professor O. M. Mitchel.

MAGNETIC VARIATION OR DECLINATION.

One of the contributions to general physics bearing upon the determination of the magnetic variation, or declination as it is now more generally called, which was commenced in my report of last year, is followed in this. The practical end is, having given a measurement of the

variation of the needle at any hour of the day, or on a particular day of the month in a certain year, to reduce it to the mean of that year, month, and day. This may be done by tables given in the memoir, Appendix No. 23, or by the diagram on Sketch No. 7. The diagram corresponds to a table of double entry, the hours of the day being at the top and bottom, and the months of the year at the sides. The reductions for the position of the needle are represented by the lines of equal change for every half minute. A surface is thus artificially represented, which shows to the eye, in curves of equal reduction, the changes of the needle—one surface for the changes to the east, and one for those to the west. Comparing this with the mode of representing surfaces (of the ground for example) by horizontal curves, the hills and valleys represent the changes. The average line is also traced on the diagram. If, then, we would find a correction to be applied to a certain observation, we enter the diagram with the hour of the day, and draw a line parallel to the side border, and with the month, drawing a line parallel to the upper or lower edge; from the meeting point of these two lines erect a perpendicular to the plane of the paper, and where it strikes the curved surface gives the amount of change; or practically, at the intersection of the two lines first drawn will be found the projection of the point which shows the change. If it is on one of the curves, simply read it off; if between two, make a proportionate allowance.

Another practical matter derived from this discussion is, the best time of day for observing the magnetic variation. The hours during the year which vary least from the average of the whole year are those corresponding to the greatest western declination, and to the morning mean declination. On the average, these hours are 1*h.* 16*m.* p. m. and 10*h.* 26*m.* a. m., both of which are very convenient for working. The greatest difference in the time of occurrence between any one month and the average of all is, for the greatest western declination thirty-one minutes, and for the mean twenty-eight minutes. So the surveyor or navigator will be safest in using these hours for his determinations of the variation of the compass. The whole subject is eminently a practical one, though reached by a scientific discussion which seems to pass much beyond the bounds of the practical.

A general idea of the discussion may be had as follows: The observations consisted in ascertaining, by Gauss's new instruments, the position of the magnetic needle or bar every hour or every two hours in the twenty-four for a period of five years, or from 1840 to 1845. The history of them and of their publication is given in my first paper.* The first step was to examine the observations, and take out those which were affected by auroras or magnetic storms. This was done by Peirce's criterion, a mathematical formula which, by comparing separate observations with the mean, enables the computer to know whether the result will be nearer the truth, or more probable with or without the observation in question, and thus to reject doubtful observations—not by an arbitrary process or by a biassed judgment, but by rigid computations, which show these results to be accepted and those to be rejected. The magnetic observations thus freed from disturbances, the places of the rejected ones are filled up by the most probable averages. In examining the results, the first large change appeared, having a period of eleven years. This had been, previously, well made out by General Sabine, in the discussion of the results of the British observations in the great combined system with which these Girard College observations had been connected. The agreement of this period, and of the disturbances with the period of the greatest number, and magnitude of the solar spots was traced, giving thus a glimpse of the meteorology of the sun by the study of these changes in the magnetism of the earth. Taking out these periodical changes, the results were next examined for daily, monthly, and yearly change.

A table being formed in which the hourly mean position of the needle for each month is compared with the average position for the month, the law of change from hour to hour, and from month to month, appears. The annual change from month to month follows the earth's

* Smithsonian Contributions to Knowledge, 1859, Vol XI; and Coast Survey Report for 1859, Appendix No. 22.

motion in its orbit. It is greater here in the winter than in the summer months. Taking this change as manifested from hour to hour in the twenty-four, it shows the points of greatest variation, the first between six and seven a. m., disappearing at a quarter before ten a. m.; the second, smaller than the first, at one o'clock p. m., disappearing shortly after five p. m.; and a third, still smaller, after nine p. m., disappearing half an hour before midnight. These changes cause the north end of the needle to be deflected more to the eastward in the summer about six or seven o'clock a. m., and more to the westward in winter. At about one o'clock p. m. they cause the north end of the magnet to be carried more to the westward in summer, and to the eastward in winter, and so cause an increase of apparent diurnal movement in summer, and a diminution in winter. This amounts to between two and three minutes of arc at Philadelphia.

Taking out the annual change and its inequality, we can compute the mean annual value of the regular solar diurnal variation with an uncertainty, at the greatest, of but eleven seconds of arc. In the early morning hours the north end of the magnet moves to the eastward, reaching its least western deflection at about a quarter before eight a. m. It then returns westward, reaching its greatest western deflection at a quarter after one o'clock p. m., and again moves slowly to the eastward. The diurnal curve presents but a single wave, slightly interrupted by a deviation in the hours near midnight. This, it will be perceived, is an important step in the theory of the sun's action on the magnet for the apparently double-headed curve of the day, that is, a curve with two maxima and two minima, has been reduced to a single-headed one, or one with but a maximum and minimum. In other words, the solar magnetic tide of the day, instead of having, like the tides of the ocean, two flows and two ebbs in about twenty-four hours, has but one ebb and one flow, resembling the tides of the Gulf of Mexico, and not those of the Atlantic. And this is contrary to the appearance of things from the crude observations which presented two tides.

After thus representing the changes of short period in the sun's action, that from year to year is deduced, and the residual numbers are arranged so as to represent the moon's action on the needle. The discussion of this constitutes the subject of the next paper, Appendix No. 24, in which are shown, following, as before, the methods of discussion of Sabine, Lloyd, and Kreil, the double lunar magnetic tide which takes place in the lunar day, and amounting to some twenty-four seconds of arc; the single tide in the same day, which, combined with the former, gives the observed magnetic tide; the inequality corresponding to a solar year; the probable changes of position at the change and full; and the doubtful effect of the moon's position north or south of the equator, or of the moon's distance from the earth. This exhausts the subject as far as we now perceive, and reduces the residual quantities to numbers corresponding to the probable errors of the quantities used.

The connection of the solar spots with magnetic disturbances, and general changes of magnetic declination having been made out with a very reasonable degree of probability, I have not hesitated to avail myself of Assistant Schott's offer to observe regularly the solar spots after the method of Carrington and Wolf. They are observed by projecting the sun's image upon a screen, and drawings are made of the sun's disk for position and number of spots, and also of the several spots in detail. The mode of observing, and the results for seven months, are given in Appendix No. 25, in Mr. Schott's report. This is an interesting contribution to general physics, having a direct bearing also upon our magnetic results.

MAGNETIC STATIONS AT KEY WEST AND EASTPORT.

Two magnetic stations have been established, which, in communication with the magnetic observatory of the University of Mississippi, will furnish the required corrections for our Atlantic and Gulf magnetic observations. The observations at these stations will be in connection with the new series of observations contemplated under the direction of the British

government. The Key West station is established in connection with the Smithsonian Institution, and the instruments are those which were furnished for the observatory in the Smithsonian grounds. The report of Professor Trowbridge, who established the station at Key West, gives a full account of the station due to the liberality of the Engineer department and its fitting up; of the instruments, their mounting and adjustment; of the determinations of their scales and corrections; of the method of applying photography to the registration of the magnetic results; of the experiments to determine the constants of the instruments and the magnetic constants of the station; the provisions made for the continuance of absolute observations of declination, dip, and intensity, with portable instruments, and of the differential observations of the magnetic elements by the photographic registry of results, and the like.—(See Appendix No. 26.) I have judged it expedient to publish this report in full, as it will be useful in the case of establishing similar stations in the United States. The photographic traces are now regularly received at the office of the Coast Survey in Washington.

The station at Eastport, Maine, is combined with a tidal station, and is for absolute determinations, on four days of each month, of the declination, dip, and intensity. The observations were commenced in January, 1860. The Appendix No. 27 contains a memorandum in reference to the station by Assistant L. F. Pourtales.

A continuation of the list of determinations for magnetic declination, dip, and intensity, given in my report for 1858, is contained in the Appendix (No. 28) of this report, and an additional list giving the results of determinations made by Assistant C. A. Schott, in Appendix No. 29.

GULF STREAM.

The results of the Coast Survey explorations of the Gulf Stream, in as condensed a form as I have been able to give them, are contained in Appendix No. 17, being the substance of a lecture delivered before the American Association for the Advancement of Science, and by their request. The progress, especially of the temperature investigations, those most characteristic of the stream, is stated under the following heads:

I. Type curves of law of temperature, with depth, at the most characteristic positions.

II. Type curves of disturbance of temperature across the stream. (*a*) Curves of temperature at the same depths. (*b*) Curves of depths at the same temperature.

III. The cold wall.

The diagrams will enable the reader to follow the different statements made in the lecture, and the final description of the stream from the Gulf of Mexico to the parallel of forty, north latitude, will be understood by the general map, (No. 21,) which is the last of the Gulf Stream plates.

This summary, though drawn from previous discussions in my reports, presents the subject in a more methodical way than I have heretofore been able to handle it, and so may be useful to navigators who desire to become familiar with this important feature of the coast navigation, so as to subject its peculiarities of warmth and current to their uses.

FORMULÆ, ETC.

For the purposes of the field parties, tables of the form given in Appendix No. 36 are used in computing latitudes and longitudes from the triangulation, and they are now presented for practical use to avoid the necessity for frequent copying, which has been hitherto required of the Computing Division of the office in order to meet the calls for them.

In the discussion of physical problems, frequent application is made of formulæ for interpolation. The formulæ of Cauchy being very useful in many cases, a notice of them has been prepared by Assistant C. A. Schott, accompanied by an example for illustration, which will be found in Appendix No. 37.

To facilitate the construction of contour lines on the plane-table sheets in localities in which the surface level is much broken, the table in Appendix No. 38 has been computed by Mr. Schott. It is based on the units of length actually in use, and will be found convenient for the purposes intended by topographers generally.

HEIGHTS.

In conjunction with the Smithsonian Institution, we have been engaged for some years in endeavoring to obtain all the data existing for heights in North America. During the past year a new circular has been issued to the engineers, presidents and superintendents of railroads, and to geologists, explorers, and other men of science, to obtain additional results, and with much success. To the entire number issued, two hundred and fifty replies have been received. These furnish data for the height above tide of about thirteen thousand points, of which a large portion has been contributed by the explorations for routes for the Pacific railroad, and a considerable number by other surveys of the government. The material received has been mapped by Mr. W. L. Nicholson, who is charged with the details of the work, so as to indicate whether the data were likely to suffice for the construction of contour lines of the surface of the continent, and to show where they would be deficient for that purpose. Sources of information have been pointed out, of which we have not yet been fully able to avail ourselves, but the work has, in a general way, made good progress, and will be earnestly prosecuted.

EXPERIMENTAL INQUIRIES.

During the year a series of very elaborate experiments has been in progress under the general direction of Assistant J. E. Hilgard, by Mr. W. L. Nicholson and Mr. Joseph Saxton, of the Weights and Measures, assisted by Mr. Thomas McDonnell, on the comparison of the standard bar, used as a comparing bar in the base apparatus, with the standard metre, and also on the expansion of the standard bar by heat. These are very laborious and difficult experiments, and the details are not yet ripe for a report.

INSTRUMENTS AND APPARATUS.

As promised in my last report, the apparatus for deep-sea soundings, invented by Professor Trowbridge, has been tried in the soundings across the Gulf Stream, from the Tortugas to the southward and westward, and then to the coast of Cuba, west of Havana. The results are very satisfactory, and Professor Trowbridge is now engaged in adapting the invention to one of the vessels of the survey for regular use.

Assistant Henry Mitchell has invented two ingenious instruments for bringing up specimens of mud and sand from below the surface of the bottom on shoals, &c., at moderate depths. They are figured in Sketch No. 40, and described in Appendix No. 39.

Mr. John R. Gilliss, temporarily employed in the Tidal Division, has invented a three-arm divider for decomposing tidal curves, which is quite a labor-saving piece of apparatus. A drawing is shown on Sketch No. 40, and the method of applying the instrument in Appendix No. 40.

OFFICERS OF THE ARMY.

Lieutenants W. G. Gill, Geo. Bell, N. H. McLean, Wm. Craig, and O. D. Greene, have been detailed for coast service within the year. Lieuts. Gill, Bell, Craig, and Greene, are attached to field parties to give them training as chiefs of triangulation parties, and Lieut. McLean has been assigned to the office. Orders were issued detaching Lieut. Hill from the survey, but, at my earnest request, the Hon. Secretary of War allowed him to remain until after the close of the session of Congress, his services being of special importance in the office;

and the period of Lieut. Terrill's service was extended, on my application, by the same officer, to that established by the regulations of the War Department.

Lieut. Thos. Wilson has been in charge of the Drawing Division, in place of Lieut. Tidball; Lieut. J. R. Smead, of the Engraving Division, in place of Lieut. Saxton; and Lieut. N. H. McLean, in charge of the Miscellaneous Division, in place of Lieut. Roy. Lieuts. Tidball, Saxton, and Roy, as stated in my last report, have been relieved from service on the Coast Survey.

The names of the officers of the army now serving on the Coast Survey are given in Appendix No. 3.

OFFICERS OF THE NAVY.

The following changes have taken place in the officers of the navy attached to the Coast Survey during the past year: Lieutenant Guthrie has taken the place of Lieutenant T. B. Huger, in command of the steamer Walker. Lieut. Washington Gwathmey, Passed Assistant Surgeon James Suddards, and Midshipman F. B. Blake, have been detached, and Lieut. W. Ronckendorff and Lieut. Silas Bent have been attached. The first-named officer has commanded the schooner Arago, and the latter named is attached to the office, rendering very useful service in the Hydrographic Division in the revision of charts, for which his experience and qualifications are of a high order.

Other changes which have been effected at the close of the surveying season, as operating more particularly on the service of the coming year, will be more properly stated in my next report.

A complete list of the officers of the navy on Coast Survey service, September 1, 1860, is given in the Appendix No. 5.

The inspection and repairs of the vessels used in the survey have been continued under the charge of Commander S. S. Lee, whose zeal and industry I have already had occasion to recognize.

AIDS TO NAVIGATION.

The recommendations of the chiefs of hydrographic parties in relation to beacons, buoys, &c., will be found in Appendix No. 43. They have generally been reported at the time of receiving them, through the Treasury Department, to the Light-house Board.

OBITUARIES.

Assistant Wilson M. C. Fairfax, who died on the 8th of August, 1860, entered the Coast Survey under my predecessor in 1843. He was educated at West Point, and combined the rare qualities of field and office usefulness. It was in the latter capacity that he proposed to serve; and as a topographical draughtsman he was without a superior in the country, perhaps in the world. Combining a full mastery of theory with the feeling of the artist, his work was in accuracy and in effect of the highest order. His laborious habits and conscientious modes of action made him an example to his juniors in the service, while his amiable and retiring character secured their good will. With characteristic fidelity his labors and his life ended almost together. He died at the age of sixty-two years.

Assistant John Seib, who entered the survey in 1848, and was one of its most industrious and competent topographers, died suddenly in Washington, on his way to section V, on the 23d of December, 1859. Mr. Seib was one of those men who are exclusively devoted to their professional occupations, finding their pleasure in constant employment. Hence all his powers were concentrated upon his work, and he was always with rare intervals in the field. His amiable character made him generally regretted.

Mr. J. V. N. Throop, long known in Washington as an engraver of skill, has for many years worked on contracts for the Coast Survey, and for several been regularly engaged in the office. His health has failed within the last two years, and he died, after much suffering, on the 3d of July, 1860.

Mr. E. H. Fauntleroy, a young man of great promise, and son of one of the most efficient assistants, whose loss it was the misfortune of the Coast Survey to deplore at an early period in its progress, died suddenly at San Francisco, on the 25th of May, 1860, in the performance of his duties as aid in the party of Assistant Davidson.

From the date of his entrance on the survey, in 1858, Mr. Fauntleroy had shown himself especially adapted to the profession of his choice. Possessing all the qualities that adorn private life, he had the rare fortune to unite them with abilities of the most promising order.

His untimely death, after a brief career of usefulness, has proved as well a loss to the work under my superintendence, as a sourco of lively regret to the chief with whom he was associated.

PART II.

The detailed account is next to be given of the work in the field, afloat, and in the office, arranged in the order of geographical sections, and under each section under the sub-divisions of field-work, including geodesy, topography, and hydrography; and of office-work, including computations, drawing, and engraving of maps and charts.

SECTION I.

FROM PASSAMAQUODDY BAY TO POINT JUDITH, INCLUDING THE COAST OF THE STATES OF MAINE, NEW HAMPSHIRE, MASSACHUSETTS, AND RHODE ISLAND.—(SKETCH A, NOS. 1 AND 2.)

The details will be stated under the following heads generally:

1. The continuation of the primary triangulation of the coast of New England, with determinations as at other stations in the series for latitude, azimuth, and the magnetic elements. Special astronomical observations were made at Gunstock mountain, N. H., in connection with the solar eclipse of the 18th of July.
2. Progress made in the secondary triangulation of the coast of Maine, including part of Passamaquoddy bay.
3. The triangulation of Frenchman's bay, and determination of topographical points for its survey. This work is connected with the Epping base, Me.
4. Secondary triangulation of the coast of Maine, including the lower part of Penobscot bay and the islands at its entrance; also Rockland harbor, and the shores generally as far up as Camden, Me.
5. The completion of the triangulation of Muscongus bay. Points are furnished by this work for the plane-table survey of the rivers emptying into the bay, and for the completion of that of the Kennebec and Androscoggin.
6. Progress in the topography of the peninsula between the Sheepscot and Kennebec rivers, leaving only a small portion at its southern extremity to complete the work in that vicinity.
7. Detailed survey of the shores of Merrymeeting bay, in connection with supplementary details of topography on the shores of Kennebec river.
8. The topography of Harpswell Neck and neighboring islands, Casco bay.
9. Topographical resurvey of islands and parts of the inner harbor of Boston for commissioners.
10. Minute plane-table survey, for committee of the Massachusetts legislature, of the courses and vicinity of the Scusset and Monumet rivers, between Cape Cod bay and the head of Buzzard's bay, Mass.

11. Topography continued on the shores of Barnstable bay, between the mouth of Scusset river and Barnstable harbor.

12. In-shore hydrography extended from Damiscove island eastward across the approaches of Muscongus bay.

13. Damariscotta river sounded out and connected with the coast hydrography. Many dangerous reefs and ledges were developed in the progress of this work.

14. The development of Jeffrey's bank and Jeffrey's ledge by transverse lines and soundings made along their axes.

15. Deep-sea soundings made on a line from Cape Ann to Seal island, N. S.

16. Special hydrography executed in the vicinity of the inner harbor of Boston for commissioners.

17. A special hydrographic survey at the mouth of Scusset river (Cape Cod bay) for the legislature of Massachusetts.

18. Further development in the general hydrography of the Nantucket shoals, showing an extensive and well-defined shoal six miles long and twenty-four miles southeast from Davis's south shoal.

19. Special observations on the currents of Boston harbor, and on the tides and currents of Cape Cod bay and Buzzard's bay. These were made in connection with hydrographic resurveys for separate commissions having in charge the special interests of navigation in the two localities.

20. The establishment of a magnetic station at Eastport, Me., and determination of the magnetic elements at several stations on Cape Cod peninsula.

21. Tidal observations.

Office-work.—The drawing and engraving of coast map and chart No. 14, from Buzzard's bay to Block island; the drawing of the chart of Portland harbor; and the engraving of preliminary sea-coast chart No. 4, from Cape Cod to Saughkonnet Point, have been completed; as also the engraving of charts of Rockport harbor, Lynn harbor, Muskeget channel, (new edition,) and additions to the progress sketches and plates of charts issued in former years. Progress has been made in the drawing and engraving of preliminary sea-coast chart No. 3, from Cape Small Point to Cape Cod; also on coast maps and charts Nos. 8 and 9, from Seguin island to Cape Ann; on No. 11, from Plymouth harbor to Hyannis harbor; in the drawing of preliminary sea-coast chart No. 2, from Isle au Haut (Penobscot bay) to Cape Elizabeth; in that of the charts of the Sheepscot and Kennebec rivers; on coast map and chart No. 7, from Muscongus bay to Portland harbor; and in the engraving of coast maps and charts Nos. 12 and 13, from Monomoy to Martha's Vineyard.

Geodetic, astronomical, and magnetic observations.—The party under my immediate direction was organized early in June to continue the primary triangulation of the coast of New Hampshire and Massachusetts. The preliminaries required in the erection of signals and posting the heliotropers were attended to, as heretofore, by Assistant G. W. Dean, and the preparations required for occupying the stations were made, as usual, by Mr. Thomas McDonnell.

Station Gunstock, in the township of Gilford, Belknap county, New Hampshire, was first occupied. The measurement of horizontal angles was commenced there on the 11th of July; and the weather continuing unusually favorable, the work advanced rapidly until the 15th of August, at which date the various operations were satisfactorily completed. Arrangements were made for the immediate transfer of the party and instruments to station Wachusett mountain, situated in East Princeton township, Worcester county, Massachusetts.

While the preliminary preparations were being made at Wachusett, Assistant Dean, aided by Sub-Assistant R. E. Halter and Mr. R. H. Talcott, measured the necessary angles at the station on Unkonoonuc mountain for taking in Monadnoc with the series of primary triangles.

The operations at Gunstock included the measurement of twenty-three horizontal angles

with the thirty-inch theodolite; vertical angles with the eight-inch Gambey circle, C. S. No. 57, upon nine stations; azimuth with the large theodolite; determinations for latitude with the zenith telescope; occultations of the Pleiades observed on the night of July 13, and the eclipse of the sun on the 18th of that month, for longitude purposes; the determination of the magnetic elements; and the usual meteorological observations. These, in connection with other operations, will be noticed in more detail presently. During the latter part of the season the weather was not so favorable for work as it had been in July and August.

The measurement of horizontal angles at station Wachusett was begun on the 13th of September, and by the 16th of October the geodetic, astronomical, and magnetic observations were completed.

Primary triangulation.—At station Gunstock eleven hundred and thirteen observations were made with the thirty-inch theodolite, C. S. No. 1, upon ten signals and an elongation mark. The heights of the stations connecting with it were determined from six hundred and fifty-four measurements of vertical angles with the eight-inch Gambey vertical circle, C. S. No. 57.

At Unkonoonuc station four hundred and thirteen measurements were made with the large theodolite, on three signals, for the horizontal angles.

At Wachusett eleven hundred and seventy observations with the same theodolite were recorded. These were made on ten primary signals and the elongation mark, and the heights of nine of the stations were ascertained by three hundred and fifty measurements of the vertical angles.

The most distant signals observed on during the season were those on Gunstock and Wachusett, being about seventy-six miles from each other in a direct line. Five others upon which measurements were made were from fifty-five to seventy miles apart, and the average distance of the remaining ones was forty miles.

The relative positions of the several stations may be seen by reference to Sketch No. 1. The area embraced within the completed triangles, estimated in the usual way, is thirty-six hundred square miles.

Latitude.—With the zenith telescope, C. S. No. 5, three hundred and twenty-eight observations were made at Gunstock on forty-seven sets of stars, and the arc value of the micrometer was carefully determined from one hundred and twenty-two readings on Polaris and sixty readings on star No. 240 B. A. Catalogue, near their eastern elongation. The local time was ascertained from two hundred observations made with the twenty-four inch transit, C. S. No. 10, on forty-two zenith and circumpolar stars.

At station Wachusett three hundred and twenty-two observations with the zenith instrument were recorded, forty-six pairs of stars being used. The arc value of the micrometer was ascertained from one hundred and eighty observations upon Polaris, near eastern elongation, and the divisions of the level were determined in the usual manner with the micrometer. The local time was obtained from one hundred and six observations of zenith and circumpolar stars.

The observations for latitude and time were made by Sub-Assistant J. H. Toomer, aided by Mr. Henry W. Bache.

Longitude.—Arrangements were perfected in advance for observing the occultations of the Pleiades at Gunstock mountain in July. On the night of the 13th of that month the times of the immersion and emersion of four of the group were carefully noted.

Special preparations were also made for observing all the phases of the solar eclipse of July 18 at the same station; and for this purpose the necessary astronomical, magnetic, and meteorological instruments were adjusted, and hourly observations of the magnetic declination and horizontal force, in connection with the requisite meteorological readings, were commenced on the morning of the 16th, and continued until the evening of the 20th of July. For several days, and at times corresponding with the duration of the eclipse, the observations were recorded every two minutes. The weather at Gunstock on the morning of the 18th was

remarkably favorable, and the observations of the eclipse during its progress made by myself and assistants were quite satisfactory.

At station Wachusett arrangements were made for observing the occultations of the Pleiades on the night of October 3, but unfortunately a dense fog prevented.

Azimuth.—The astronomical meridian and the bearings of the trigonometrical lines at stations Gunstock and Wachusett were determined in the usual way with the thirty-inch theodolite. At the first-named station ninety observations were made on *Polaris*, near its eastern elongation, and eighty-four on δ *Ursæ Minoris*, near its upper culmination, in connection with one hundred and fifty-six readings on the elongation mark.

The azimuth at Wachusett was ascertained from ninety observations on *Polaris*, near eastern elongation, and seventy-two on λ *Ursæ Minoris*, near the upper culmination, in addition to one hundred and sixty observations on the elongation mark.

Magnetic observations.—At Gunstock a magnetic station was chosen near the summit of the mountain, in a northerly direction from the geodetic station. In determining the declination, five hundred observations were made on six days, and for the inclination of the needle five complete sets of observations were recorded from a nine-inch dip circle. The horizontal intensity was deduced from three sets of deflections and vibrations on three days, and the horizontal force from three hundred and ten readings of a Bifilar magnet.

At Wachusett one hundred and thirty-three observations were made, to determine the magnetic declination, on three days, and the inclination was deduced from three sets on three days. The horizontal intensity and moment of inertia were determined from four sets on four days.

The instruments used at Gunstock were declinometer C. S. No. 6, dip circle C. S. No. 9, and Bifilar magnet C. S. No. 4. At Wachusett, declinometer D. (22 C. S. No. 1) and dip circle C. S. No. 4 were used.

The azimuth and magnetic observations were made by Assistant Dean; Sub-Assistant R. E. Halter and Mr. R. H. Talcott assisted in that duty.

Meteorological observations.—The usual journals were kept during the season by Mr. Talcott, who recorded four hundred and three readings of the barometer and wet and dry bulb thermometers.

All the original records were duplicated, and the reductions made of latitude, azimuth, and magnetic observations before the party left the field.

Assistant Dean is about to resume the longitude determinations in Section VII.

Triangulation of Passamaquoddy bay, Me.—The secondary triangulation of the coast of Maine, near the northeastern boundary, was taken up by Assistant C. O. Boutelle in the first week of September, and is based on the reconnaissance made by him last year. As laid out for execution, the scheme of triangulation (Sketch No. 2) includes the coast lying north and east of a line from Cross island, to the southern head of Grand Manan, and the whole of Cobscook bay. It also embraces the western shore of Grand Manan, Campo Bello, and Deer island, and the smaller islands between East Quoddy Head and Letite Passage, with the eastern shore of the St. Croix river, from St. Andrew's to the town of St. Stephen. The progress made within these limits furnishes data sufficient for a season's topography. Lieut. George Bell, U. S. A., efficiently assisted Mr. Boutelle in the field-work.

Two first order signals, six of the second, and fifteen of the third order, have been put up, and sites selected for stations, the lines between which will include the whole of Quoddy bay.

A summary of statistics is here given as taken from the report of Assistant Boutelle:

Stations occupied	6
Objects observed on	153
Angles measured	155
Number of observations	1,025

The field-work was continued until the 1st of October.

Lieut. Bell has been assigned to duty on the coast of Texas.

Triangulation of Frenchman's bay, Me.—In the vicinity of the Epping base, and connected with it, Sub-Assistant F. P. Webber laid out, in August, a secondary triangulation to include Frenchman's bay and the adjacent coast of Maine. This work extends from Pigeon Hill primary station to Mt. Desert island, southward and westward along the coast, and northward to the town of Sullivan, at the head of the bay. Full provision was made in its progress in the determination of third order points for the plane-table survey. Messrs. Julius Kincheloe and G. U. Mayo aided in the field-work. The party used the schooner Hassler for transportation in this and in another locality of the section, to which reference will be made presently.

For plane-table purposes the positions of twenty-seven points were determined. The other particulars of the triangulation are shown in the following summary:

Signals erected	16
Stations occupied	6
Objects observed on	125
Horizontal angles measured	139
Vertical angles measured	21
Number of observations	2,274

The limits of the triangulation may be seen by Sketch No. 2.

Mr. Webber closed work for the season on the 28th of September. In addition to the field-work, he has revised and forwarded his notes and records, and furnished computations of his results.

Notes of the horizontal angles determined in connecting the Epping base with the primary triangulation, and others made in running a line of levels at Pigeon Hill, were sent to the office by Assistant Boutelle before taking the field for work at the south.

Triangulation of Penobscot bay, Me.—In pursuance of a scheme laid out and matured last season, Sub-Assistant J. A. Sullivan took the field in May, and completed observations on the signals erected in the lower part of Penobscot bay. The secondary triangulation of the coast of Maine is now continuous eastward to Isle au Haut, and includes within the limits of the work here noticed the islands at the entrance of the bay. The progress made is shown on Sketch No. 2. As the work went on, attention was given to the requirements for the plane-table survey, and points were selected sufficient for tracing the shore-line as far up as the vicinity of Camden, and the outlines of the islands between Rockland and Isle au Haut.

Sub-Assistant Sullivan was aided in the field by Messrs. McLane Tilton and J. D. Bradford. The angular measurements were completed on the 27th of June. On closing work, the schooner Peirce, which had been in the service of the triangulation party, was laid up at Belfast. Mr. Sullivan then took up the necessary computations.

The following is an abstract of the statistics connected with duty in the field:

Number of signals erected	7
Signals observed on	20
Points determined	15
Number of observations	2,868

The ten-inch No. 31 and eight-inch theodolite No. 57 were used in determining the angles.

Soon after leaving the field, Sub-Assistant Sullivan made and turned in the computations of his work, with the original record of angles and descriptions of the stations occupied by the party while under his charge.

On the 3d of September Assistant G. A. Fairfield, with the two aids of the party, took up and continued the work in Penobscot bay, establishing the third order points for topography between Owl's Head and Turkey signal, and for the survey of Rockland harbor. He also completed the measurement of angles in the secondary triangulation below Camden. The

instrument used by him was a new ten-inch theodolite (No. 91) furnished for trial by G. W. Blunt, Esq., of New York; and in reference to the results obtained with it, Mr. Fairfield says: "Of the five angles determined at Fox Rocks station, one was measured last year by Sub-Assistant Sullivan, the rest by myself with theodolite No. 91. They close the circle within 1″.09, and the angles measured with it that fill triangles were very close."

The triangulation executed by Mr. Fairfield has been computed, checked, and the results and duplicate records have been forwarded to the office. A summary of the details of his work in the field is appended:

Signals erected	16
Stations occupied	8
Points determined	27
Angles measured	134
Number of observations	1,075

The work was closed on the 20th of October, and the schooner Peirce was a few days afterwards turned over to the charge of Sub-Assistant Ferguson, at Portland.

Assistant Fairfield is preparing to return and continue duty near Cape Sable, Florida.

Triangulation of the St. George's, Medomak, Damariscotta, Kennebec, and Androscoggin rivers, Me.—In July, Sub-Assistant Webber, aided by Messrs. Kincheloe and Mayo, extended the secondary triangulation of Muscongus bay northward, so as to furnish points for the plane-table survey of the rivers connected with it. Positions were determined for the topography of the St. George as far up as Thomaston, on the shores of the Medomak to Waldoboro', and the triangulation was extended up the Damariscotta to Newcastle. That on St. George's river was carried to a junction with the secondary triangulation in Penobscot bay. Mr. Webber also furnished points for completing the topography of Merrymeeting bay, and for the plane-table survey of the Androscoggin river to Brunswick. The triangulation party moved from this vicinity and took up work at Frenchman's bay, as already stated. At eight of his stations west of the Penobscot Mr. Webber measured vertical angles on twenty-eight objects, and recorded three hundred and forty-four observations. The ten-inch Gambey, C. S. No. 63, and six-inch Brunner theodolite, C. S. No. 52, were used in this triangulation. The following are the general statistics of the work:

Signals erected	24
Stations occupied	26
Points determined	51
Objects observed on	226
Angles measured	200
Number of observations	1,272

Sketch No. 2 shows the locality of the triangulation. All the records and computations connected with it have been turned in.

The occupation of Sub-Assistant Webber's party in the schooner Hassler, during the winter and spring of the surveying year, will be stated under Section V. He is now making arrangements for returning to the southern coast. Mr. Kincheloe has been assigned to duty on the coast of California.

Topography between the Sheepscot and Kennebec rivers, Me.—Plane-table duty was resumed on the shores of the Sheepscot river by Assistant I. Hull Adams in the latter part of July, and continued under his charge until the 7th of August, when he was relieved in the charge of the party by Sub-Assistant Charles Ferguson. Mr. Adams connected his plane-table sheet of the river with the survey of the vicinity of Wiscasset, by Sub-Assistant W. H. Dennis, and then traced part of the shore-line of Oren's Mouth bay.

Sub-Assistant Ferguson took up the topography on Westport island, on the west side of the Sheepscot, at a point about six miles below Wiscasset, (Sketch No. 2,) and continued it

northerly and halfway across the island, making a connection with the work of the previous year. He then proceeded with the survey of the shores of Back river, completing also that of the adjacent side of Westport island, and including six miles or about two-thirds of its entire length. On the western side of Back river the shore-line was traced from Cushman Hill, six miles southward, or nearly to the entrance into the Kennebec. The shores of a branch called Montseag river, coming in on the same side, were also surveyed as far up as Shaddocks' bridge.

"Back river varies from one-fourth of a mile to a mile in width, runs nearly parallel to the Kennebec, and has one entrance into that river about eight miles below Wiscasset. At that point the breadth of the Woolwich peninsula, which lies between the two rivers, is about four miles. Several large fisheries are established at headlands along the line of Back river."

The amount of work done between the Sheepscot and Kennebec is shown in the following statistics:

Shore-line traced	35 miles.
Roads	18 "
Area (square miles)	$10\frac{3}{4}$

Assistant Adams is now prosecuting plane-table duty in Section III, and Sub-Assistant Ferguson is about to resume work on the eastern coast of Florida.

Topography of Merrymeeting bay and its vicinity, Me.—The detailed survey of the Kennebec river was resumed on the 21st of June, and has been extended from the vicinity of Bath, partly across the neck between that city and the south shore of the Androscoggin. The work above Bath was continued, and progress has been made in the topography of the shores of Merrymeeting bay. Assistant R. M. Bache is still engaged in the survey, having, up to the present date, added details to two plane-table sheets, one including Merrymeeting bay, and the other the point of land between the Androscoggin and Kennebec rivers. A third sheet, which had been worked on previously, has been completed, showing the minute topography of the shores of the Kennebec above and below Bath.

The following are the statistics:

Shore-line surveyed	20 miles.
Roads	$15\frac{1}{2}$ "
Area of detailed topography, (square miles)	$6\frac{1}{2}$

Topography of Harpswell Neck and adjacent islands, Me.—In continuation of the plane-table survey of the shore and islands of Casco bay, Assistant A. W. Longfellow resumed work at Harpswell Neck on the 7th of June, and has nearly completed the details on a sheet including the Neck and the neighboring islands of Mericoneig sound. The sheet extends northward to Birch island, and contains the following details:

Shore-line	75 miles.
Roads	15 "
Area of topography, (square miles)	9

The party of Mr. Longfellow used the schooner Meredith in this work until the 20th of October, when the vessel was turned over for service on the coast of Georgia. Sketch No. 2 shows the locality in which this party was engaged during the present season. Bailey's island and a considerable part of Orr's island appear on the topographical sheet.

In the course of last winter and spring Assistant Longfellow inked and turned in three sheets containing surveys of the outer islands of Casco bay, the Green islands, and others in the vicinity of the mouth of the Presumpscot river.

Topography of islands in Boston harbor and of parts of the main.—Assistant H. L. Whiting has resurveyed, for the municipal authorities of Boston, the islands in the outer harbor which have suffered most change from the action of the waves, winds, and frost, and portions of the main similarly exposed. This survey on the scale of $\frac{1}{5000}$ gives, with great minuteness, the

present condition of the more exposed portions of the outer harbor. By comparison with the former surveys, it will enable the United States commissioners approximately to estimate the progress of destruction within the last thirteen years, and roughly to show what those islands were in form and dimensions before the trees and vegetation which once protected them were removed. The materials furnished by the wear of these islands are placed at the disposal of the currents and waves for the formation or increase of bars and shoals.

Mr. Whiting was assisted in this work by Messrs. C. Rockwell and Charles Hosmer. The party used the schooner Torrey for transportation.

Topography between Cape Cod bay and the head of Buzzard's bay, Mass.—This work was done at the expense of a committee empowered by the legislature of Massachusetts to determine the practicability of a ship canal across the Cape Cod peninsula. The details were commenced in the middle of August by Sub-Assistant W. H. Dennis, and the survey was mainly executed by him, a portion of the preliminary work only having been supplied from a plane-table sheet of Assistant A. M. Harrison.

The survey of Mr. Dennis embraced the narrow valley of about eight miles in length, through which flow the Scusset and Monumet rivers—the first into Cape Cod bay, and the last named into the upper part of Buzzard's bay, (Sketch 2.) All the details were minutely filled in on the scale of $\frac{1}{10000}$, to meet and answer such purposes as the commission might be called upon to execute in connection with the proposed improvement.

The topographical sheet which Mr. Dennis is now engaged in inking contains the following statistics:

Shore-line	6 miles.
Rivers and creeks	23½ "
Roads	27 "
Area of topography, (square miles)	4½

A summary report, made by Sub-Assistant Dennis, contains much general information bearing on the character of the soil along the proposed line of canal, the depths of the streams, prevailing winds, and nature of the changes to which the outlets would be subject.

Topography of Cape Cod bay, Mass.—In continuation of his survey of Barnstable harbor, Assistant A. M. Harrison resumed work in May, pushing the topography westward along the shore of Cape Cod bay, from the limit reached in his survey of last year. Near the mouth of Scusset river (Sketch No. 2) this work connects with the special topography referred to under the preceding head. Mr. Harrison furnished such data from his working sheet as came within the area surveyed by Sub-Assistant Dennis. Sub-Assistant P. C. F. West and Mr. W. W. Harding were attached to the party of Assistant Harrison. Mr. A. W. Thompson was also reassigned to duty in it in August, but after a short period of service was compelled to leave it in consequence of serious illness. The field-work of Assistant Harrison was continued until the 10th of November, with the following result in statistics:

Shore-line traced	12¾ miles.
Creek and marsh or ponds	110 "
Roads	58 "
Area of topography, (square miles)	15¾

Hydrography of Muscongus bay, Me.—The in-shore hydrography of the coast of Maine has been extended from Damiscove island eastward to Manhegan island by the party of Lieut. Comg. T. S. Phelps, U. S. N., Assistant Coast Survey, with the steamer Vixen. In the progress of the work the soundings required to complete the hydrography of the Sheepscot river were made, and supplementary work executed between it and Damiscove island, to include Booth bay, and also the harbor of that name. It will be seen by Sketch No. 2 that the hydrographic sheet of this season completes the in-shore hydrography of the coast of

Maine eastward nearly to the entrance of Penobscot bay. This work was resumed by the party in charge of Lieut. Comg. Phelps on the 6th of August, and continued until the 1st of October. At Damiscove island the soundings join with the hydrography executed by the parties of Lieut. Comg. Bankhead and Lieut. Comg. Wilkinson.

A mile and a quarter S.SW. $\frac{1}{4}$ W. (true) from Pemaquid light-house, Lieut. Comg. Phelps discovered a small ledge with only four fathoms of water on it, and in the channel-way of Booth bay two rocks, one with only ten feet, the other in three and a quarter fathoms, and a ledge with three and a half fathoms. The position of these dangers to navigation are more particularly described in Appendix No. 9.

The following are the statistics of the hydrographic work:

Miles run in sounding	841
Angles taken	1,928
Number of soundings	7,860
Area sounded, (square miles)	230

Other special developments made in hydrography by the party in the Vixen will be mentioned in this chapter, and its previous general operations of the season under Section VII.

Hydrography of Damariscotta river and Liniken's bay, Me.—Connecting the work at Damiscove island with the in-shore hydrography mentioned under the last head, Lieut. Comg. J. P. Bankhead, U. S. N., Assistant Coast Survey, with his party in the schooner Crawford, sounded out the approaches and extended the hydrographic survey of the Damariscotta river to a point twelve miles above the line of junction with the hydrography of Lieut. Comg. Phelps. This survey takes in Liniken's bay, and has developed many dangerous reefs and ledges outside of the entrance of the Damariscotta.

For the reduction of soundings the tides were observed by the hydrographic party night and day during a period of six weeks.

Lieut. Comg. Bankhead commenced work on the 20th of July, and completed the survey within the limits of his projection by the 10th of September.

The following synopsis comprises the general statistics:

Miles run in sounding	520
Angles determined	2,920
Casts of the lead	16,833
Area sounded, (square miles)	21

The following remark is taken from the report of Lieut. Comg. Bankhead: "The want of a correct chart of that locality (entrance of the Damariscotta) is much felt, and the desire that one should soon be published was frequently expressed to me by the coasters and fishermen belonging in the vicinity."

The part of the river included in the survey of this season is shown on Sketch No. 2.

Lieut. Comg. Bankhead was engaged in the hydrography of Section V during the first half of the working season, and is now preparing to return there to continue duty on the coast of Florida and Georgia.

Early in the present surveying year the original sheet of soundings made between Cape Small and Damiscove island, by the party of Lieut. Comg. Wilkinson, was received at the office, with the records of soundings, angles, and tidal observations. The journals of the work done last year in Casco bay have also been turned in.

Jeffrey's bank.—This bank extends about twenty-seven nautical miles in a northeast and southwest direction, and lies off the entrance to Penobscot bay, at a distance of about thirty-five miles. The bank itself was sounded out and developed in contour by Lieut. Comg. Phelps, with the steamer Vixen, in the beginning of October. The least depth found was forty-six fathoms, within an approximate distance of about twenty-eight miles from Matinicus

light. The position of the bank is marked on Sketch No. 2. Sixty-three casts were made on it with the lead.

Jeffrey's ledge.—This hydrographic feature of the coast of New England was developed in September last by Lieut. Comg. John Wilkinson, U. S. N., with the steamer Corwin. Traverse lines were run across it, and a line of soundings along its axis, which stretches nearly fifty nautical miles abreast of the coast. In sixty-four soundings the least depth found was thirty fathoms, at a point near the middle of the ledge.

The position of Jeffrey's ledge is marked on the progress Sketch No. 2.

Deep-sea soundings.—Lieut. Comg. Wilkinson, in the steamer Corwin, in the early part of September, carried a line of soundings from Cape Ann, northward and eastward, to the vicinity of Seal island, N. S., but there encountering a severe gale was compelled to scud, and so was unable to make soundings in returning to the coast. In a run outward of two hundred miles, sixty-three casts were made with the lead. The greatest depth found was one hundred and ninety-five fathoms, in the meridian of Damiscove island. The line was interrupted at a position about twenty-five miles southwest of Seal Island light. Its course is marked on Sketch No. 1.

The original sheet containing the off-shore soundings made last year by Lieut. Comg. Murray, between the Isles of Shoal and Seal island, and the chart of in-shore work from Cape Elizabeth to Kennebunkport, have been completed, and registered at the office.

Re-examination of Boston harbor for changes.—At the request of the United States commissioners on Boston harbor, and at the cost of the municipal authorities, a resurvey was made during last summer of the inner harbor, and an examination in the main channel of the outer harbor, for comparison with the hydrography of 1847. These surveys were made by Lieut. Comg. Wilkinson, in the steamer Corwin. The comparative map of the inner harbor, showing the changes since the survey of Lieut. Comg. Charles H. Davis, U. S. N., Assistant Coast Survey, in 1847, is of great value, indicating the direction and amount of change, and in conjunction with the current and other physical observations, the causes of those changes.

The steamer Corwin was placed at the disposal of the commissioners to make personal examinations of portions of the harbor where changes of importance had occurred.

While engaged in the special duty alluded to in Boston harbor, Lieut. Comg. Wilkinson discovered a rock dangerous to navigation for vessels of large draught in passing through the narrows. It was found near the middle of the channel, and in four fathoms water, its crest rising to a peak, with only seventeen feet of water on it at mean low tide, or fifteen feet and three-tenths at low water of spring tides. The bearings and ranges from this obstacle to navigation, which I have called, after the name of the vessel, *Corwin Rock*, were published in the usual form, in September last, as a notice to mariners.—(See Appendix No. 10.)

Hydrography of Cape Cod bay, Mass.—In the immediate vicinity of the mouth of Scusset river a minute hydrographic survey was made with the boats of the steamer Corwin, by the party of Lieut. Comg. Wilkinson, in the latter part of September. The soundings were carried about half a mile south and east, and two miles north and west of the mouth of the river, and extended rather more than two miles outward from the shore of Cape Cod bay.

A tidal station was established by the hydrographic party near the point occupied for observations by Assistant Mitchell, his bench-mark being used in determining a plane of reference for the soundings. On the completion of the work the steamer Corwin returned to Boston. The following are statistics of the soundings:

Miles run	72½
Angles	538
Casts of the lead	2,673
Area, (square miles)	5

This hydrography was executed in compliance with a request from commissioners who have under consideration the practicability of a ship canal to connect the waters of Cape Cod bay and Buzzard's bay so as to avoid the sea navigation by the Nantucket shoals.

Hydrography of the Nantucket shoals.—My attention having been called by George W. Blunt, esq., of New York, to the existence of a rip southeast of Davis's shoal, reported by the commander of the steamship Asia, Lieut. Comg. Phelps was instructed to examine the locality, and did so in the latter part of October, after closing work in the northern part of the section. In prosecuting this duty an extensive shoal was discovered outside, and to the northeastward of the rip in question, and both are thus referred to by Lieut. Comg. Phelps:

"Near the position given by the captain of the Asia is a well-defined rip corresponding to his description, 'about a mile long, and a quarter of a mile broad,' with eleven fathoms water on it."

"About half a mile eastward of the rip lies the south point of a shoal, which extends about N.NE. a distance of six and a half nautical miles, with ten to ten and a half fathoms in several places. Both shoals are distinctly marked as well on the flood as on ebb tides, with deep and smooth water between them."

"These shoals lie between the latitudes 40° 46′ and 40° 53′ N., and longitudes 69° 19′ and 69° 25′ W., and about twenty-four miles from Davis's south shoal light-boat."—(See Appendix No. 11.)

Tides and currents of Boston harbor.—A physical examination of Boston harbor and approaches was commenced during the past season, under the direction of the harbor commissioners, and at the expense of the city of Boston.

Inquiries have been instituted relative to the action of tides, currents, waves, and other natural agencies, upon the channels and basins. It is designed by this investigation to determine definitely the causes of the contraction of the channels and the increase of the flats, which has been going on for many years, and which threatens to destroy the port.

With the consent of the Secretary of the Treasury, the party of Assistant Henry Mitchell was sent with the schooner Bailey to execute this work. Operations were commenced in the latter part of July, and continued until late in the autumn.

Mr. Mitchell reports the occupation of about sixty current stations and ten tidal stations, together with a large number of special examinations of deposits, of temperatures at different depths, of specific gravities of land and sea water, and some chemical experiments. Varied as these observations have been, the results show that practical objects have been kept steadily in view, and that our study would not be complete without all of them.

At nearly all the current stations the observations were extended to two, three, or even four different depths, in order that no movement of the sea might escape notice, and that the precise amount of scouring power exerted upon the channel-bed might be measured. The importance of this careful scrutiny is illustrated by many of the results. It was found that the upper stratum—that lying above the level of the flats and shoals—maintains to a great degree an independent movement often at variance with that of deeper strata.

The tidal stations were mostly occupied for short series of observations only; although in one case, that of the station at Boston lower light-house, the observations were kept up six weeks.

The examinations were commenced at a point three miles seaward of the lower light, and extended in a more or less connected chain to the head of Mystic river.

In Mystic river, and in the ponds at its source, some very curious results were obtained, bearing upon the mutual action of fresh and salt water upon each other. It was ascertained that distinct strata of water exist in the lower Mystic pond, whose specific gravities, temperatures, and chemical constitutions present striking contrasts. This pond is some seventy feet in depth. The upper sixteen feet is apparently pure fresh water; below this a narrow belt of

salt water is found; and yet lower, from the depth of twenty feet to the bottom, a mass of sulphurous salt water exists, which is highly offensive to taste and smell. The hydrometer gave something like regular variations in the densities for different depths; but our thermometers gave us sharp contrasts of temperatures between the sulphurous stratum and the water above.

Chemical tests for sulphur were unaffected above a plane lying 19.9 feet below the surface. Bands of copper, allowed to hang vertically from a float, were found, after a few hours, to be blackened below the plane mentioned, and the limit of the sulphuretted portion was sharply defined.

The observations on the action of waves were made by noting the changes of position of articles placed on the shores. Those articles were of different forms and specific gravities, so that the comparative forces of the waves created by different storms could be measured. Unfortunately for these inquiries, the quiet season offered no opportunity for any remarkable observations. Trials were made, however, with some success at Lovell's, Gallop's, and Deer islands, as well as at Brewster bar and Point Shirley.

Some few computations that have been made of the current observations by the Coast Survey method show that when this work is complete the causes of trouble in Boston harbor may be defined accurately.

As was anticipated at the commencement of this investigation, a second season's work is absolutely necessary to develop the details of these operations.

The burden of these observations fell principally upon the aids, whose untiring devotion to their work has secured these reliable results. The larger portion of the current observations in the harbor were made by Mr. Bright, while in the examination of the Mystic river; Mr. Heberton took charge of the records; Mr. Johnson discharged various duties, and made many observations.

Observations on tides and currents in Cape Cod bay and Buzzard's bay, Mass.—For the purposes and at the expense of a committee of the Massachusetts legislature, having in charge the question of determining on the practicability of a ship canal across the Cape Cod peninsula, series of observations were made in the course of the summer at the mouth of Scusset river and in the adjacent parts of Cape Cod bay, and in Buzzard's bay, near the mouth of Back River harbor. These were conducted by Assistant Henry Mitchell, aided throughout by Mr. W. T. Bright, and during the latter part of the season by Mr. E. P. Heberton.

In Cape Cod bay two tide-gauges were found necessary, in consequence of the great range in the rise and fall, as well as the very gradual slope of the beach. One was placed at a distance from the shore, supported by iron rods, so as to afford sufficient steadiness, and at the same time be secure from the disturbing effect of the waves. The second instrument was secured by a pile of the form devised by Mr. Mitchell, and described in Appendix No. 26 of my annual report for 1859. With these two gauges three thousaud observations were recorded, comprising the high and low waters between the 17th of July and 18th of August. Nearly double the number of observations were taken in Back River harbor on an ordinary staff-gauge, no peculiar structures being required in the quiet basin near the head of Buzzard's bay. On both sides of the peninsula the simultaneous observations were referred to bench-marks cut on large rocks.

Assistant Mitchell having observed that the temperature of the water was not the same in the two basins, the observers were provided with standard thermometers, and, during the last half of the tidal series, noted the temperatures for comparison.

Among the interesting results developed by Mr. Mitchell is the fact that the tide waves of the two bays, the shores of which are within eight miles of each other, were found not only dissimilar in ranges and epochs, but also in general figure; so that, on the supposition that the mean level of the sea is a plane common to both basins, the relative alternate elevations and

depressions do not attain the same maximum in the two bays. The greatest depression of Cape Cod bay, below Buzzard's bay, occurs about one hour after low water of the former place, and amounts, at an average, to 4.66 feet; whereas, about six hours later, Buzzard's bay reaches its greatest depression below Cape Cod bay, and the average difference of elevation is found to be 5.79 feet. Hence, although the total interchanges of water through a canal connecting these basins would be nearly the same in both directions, (supposing the mean level the same,) the maximum velocity should appear before the current ceases to set westward.

The currents of the two bays were also observed, the schooner Bailey having been assigned to the use of the party for that purpose. In Buzzard's bay four stations were occupied, and three in Cape Cod bay. The observations were made half-hourly, night and day, not only at the surface, but also on the movements of the water at different depths; the usual length of each series being twenty-five hours, so as to embrace an entire tidal day.

The changes in the elevation of the beach of Cape Cod bay were observed by repeating long lines of levellings after several easterly storms; and the movements of shingle were determined by recording the changes in position of articles deposited for the purpose, those selected being distinguishable from the material naturally thrown up.

The current observations revealed the existence of a coast current which sweeps along the westerly part of Cape Cod bay, and there takes a course northward. In the vicinity of the mouth of Scusset river it is feeble, but it gathers considerable strength further to the north. With reference to this current, Assistant Mitchell remarks: "The most singular fact observed concerning this current was its low temperature during the warm season at which our observations were made. While the mean temperature of the water in Back River harbor (Buzzard's bay) attained a height of 73 degrees, or a little above that of the air in shade, the water of Cape Cod bay reached only 54 degrees."

The observations show that the currents below are a little stronger than those at the surface in Cape Cod bay. At Scusset the levellings of the beach, though made only after moderate storms, did not show very large changes of elevation; but the movement of shingle to the southward was noticed to be remarkably active at such times.

The direct bearing of facts like those, which are here only partially alluded to, on the construction of a ship canal to join two seas, will be at once comprehended.

Magnetic observations.—In January last a magnetic station was established at Eastport, Maine, as a standard of comparison for the determinations made from time to time at other points on the northeastern coast of the United States. With the view of obtaining a continuous series of observations the station was placed in charge of Mr. G. B. Vose, and furnished with a dip circle and magnetometer. Records have been regularly received, but the value of the observations was found to be impaired by the unsteadiness of the magnetic axis of the collimator. Assistant L. F. Pourtales visited the station in August, and remedied the defect on ascertaining its cause. His description of the station and instruments used is given in Appendix No. 27.

At Wellfleet, Provincetown, and Chatham, (Cape Cod peninsula,) Assistant Charles A. Schott occupied magnetic stations in August, and determined at each the declination, dip and intensity by independent results obtained on different days. These three are the most northern in a series of ten stations at which observations were made during the month just named and the one following. Reference to the others will be made under Section II.

The instruments used were the Jones' magnetometer, C. S. No. 6, and the Barrow dip circle, C. S. No. 9. Time was noted on the Hutton chronometer 211. At each station the astronomical azimuth and local time were determined by means of the theodolite of the magnetometer, mounted for the purpose on the same stand. In observing the sun's upper and lower, and first and second limb, six sets of observations of three readings each were recorded.

For the declination half-hourly readings were taken, extending generally from the morning minimum to the afternoon maximum.

Two sets of vibrations, giving six separate results, in an aggregate of one hundred and fifty vibrations, were taken each day for ascertaining the magnetic intensity. For the dip four sets were observed daily with needle No. 1, with verifying observations in the immediate vicinity of the station.

Assistant A. S. Wadsworth accompanied Mr. Schott and assisted in the observations. Appendix No. 29 contains the results deduced from them for the stations on Cape Cod peninsula and others in the adjoining section. The original record, with a duplicate and the first reduction of the observations, have been placed in the office by Assistant Schott.

Tidal observations.—Early in the present surveying year a tidal station was established at Eastport, Maine. A self-registering gauge has been put up there and kept in operation by Mr. G. B. Vose, who has also recorded observations from a tape or belt-gauge for comparison, the great height of the tide at Eastport rendering such a comparison a matter of necessity in deducing close results.

The series of observations of high and low water at the Charlestown navy yard, Mass , has been continued during the year with great regularity by Mr. T. E. Ready. It has now been maintained for thirteen years, with the loss of but very few observations, and the record, if kept up a few years longer with fidelity, will constitute one of the most valuable series of tidal observations that has ever been made in any country. So far the registers have been highly creditable to the observers, and have already furnished data which have been much wanted for theoretical investigations of the laws governing the tides.

SECTION II.

FROM POINT JUDITH TO CAPE HENLOPEN, INCLUDING THE COAST OF THE STATES OF CONNECTICUT, NEW YORK, NEW JERSEY, PENNSYLVANIA, AND PART OF DELAWARE.—(SKETCH B, No. 6.)

I have elsewhere referred to the wreck of the steamer Walker, on the 21st of June of the present year. This disaster, which involved loss of life to twenty of her crew, with the total loss of the vessel and all the records on board, was occasioned by collision with a schooner laden with coal, and occurred about three o'clock in the morning, while the Walker was off Absecom, New Jersey, in command of Lieutenant J. J. Guthrie, U. S. N., and on her passage from Norfolk to New York. The officers of the Walker and survivors of her crew were rescued from imminent peril by Captain L. J. Hudson, of the schooner *R. G. Porter*, and safely conveyed to May's Landing, on the coast of New Jersey. The steamer sunk in less than half an hour after the collision, which took place about twelve miles from land.

Notices of the work done in this section will be arranged as follows:

1. Reconnaisance for connecting the Epping base with the Fire island base, through a direct line.
2. The completion of the main and secondary triangulation of Hudson river to the vicinity of Troy, New York.
3. Extension of the topographical survey of the shores of the Hudson to Tarrytown and Piermont. The detailed work is now complete from these points to the entrance of New York bay.
4. Supplementary work in the vicinity of Williamsburg and Rockaway. This furnishes the details required to complete the harbor commissioners' map of New York bay and harbor.
5. The advance of the regular hydrography of the Hudson river, from Poughkeepsie to Rhinebeck. The soundings below Rhinebeck are complete to the approaches of New York harbor.
6. Hydrographic resurvey of the False Hook, at the approaches of New York bay, and

determination of the character of changes in the vicinity of Sandy Hook. A rocky spot, fifteen miles to the eastward of the New York light-boat, was developed by the same party.

7. Magnetic observations made at several stations on Long Island and on the coast of New Jersey.

8. Tidal observations.

Office-work.—Progress has been made in the drawing and engraving of a map of the Hudson river from New York to Sing Sing, and on coast map and chart No. 21, New York bay and harbor. A chart of Hempstead harbor has been drawn and engraved, and the engraving of coast maps and charts Nos. 15, 16, and 17, Long Island sound, (new edition,) and No. 19, middle part of the southern coast of Long Island, has been completed. Additions have been made to the progress sketch, a separate drawing has been made of Coenties' reef, and a new plate engraved for the chart of Captain's island, east and west.

In acknowledging the receipt of copies of some of the maps of this section used by him in adjusting a narrative of incidents connected with the revolutionary war, the following remark is made by Henry B. Dawson, esq., of Morrisania, N. Y.: "Hours and days have been spent in laborious investigations concerning apparent contradictions in descriptions of places attacked, &c., which these maps would have shown in as many minutes, with greater certainty."

Reconnaissance.—The occupation of Wachusett mountain, affording at the same time ready means in part for connecting the base on Epping plains with the one on Fire island beach through a direct series of triangles, Assistant C. O. Boutelle was detailed in June to select the stations necessary for joining the entire work of the section with that of Section II. He was engaged on this reconnaissance until the 7th of August.

Triangulation of Hudson river, N. Y.—Assistant Edmund Blunt took the field early in July in the vicinity of New Baltimore, and conducted the triangulation of the Hudson from thence upwards to Troy, measuring throughout, as has been done on the lower part of the river, a main and secondary series of triangles. He also determined all the points required for plane-table use. The complete triangulation of the Hudson reached the vicinity of Troy in the latter part of October. Sketch No. 6 shows the range and general character of the triangulation.

Lieut. W. G. Gill, U. S. A., assisted Mr. Blunt in the field-work.

A synopsis of the statistics is appended:

Stations occupied	19
Number of observations	3,606
Area of triangulation, (square miles)	92

Fourteen volumes, containing the field-notes of the triangulation done on the Hudson in 1858; a volume of the horizontal angles measured in 1859, with an abstract of the same; and descriptions of the stations last occupied have been turned in by Mr. Blunt.

Lieut. Gill is about to proceed with a party for separate duty on the eastern coast of Florida.

Topography of Hudson river, N. Y.—The detailed survey of the Hudson has been advanced northward along its eastern side to the vicinity of Tarrytown, and the survey of the western shore completed upwards to Piermont.

This work was resumed in the middle of July by Sub-Assistant John Mechan, and joins near Hastings (Sketch No. 6) with the limits of his survey of last year. On the west bank the topography was taken up below Rockland. Both of these villages, as also Dobb's Ferry, Irvington, and Piermont, are included in the details of the survey made this season. The plane-table sheet embraces all the surface features comprised between the eastern bank of the river and the public road, which follows its course at the distance of about half a mile. A prolongation of the palisades appears on the sheet as the principal feature of the opposite side of the Hudson, between Rockland and Piermont. The heights are exhibited on it by contour

lines. About a mile and a half below Rockland, Mr. Mechan's work joins with Assistant Whiting's survey of the palisades. The following summary gives the statistics of progress made up to the 1st of October, when the plane-table work was discontinued for the season:

Shore-line surveyed	18 miles.
Roads	29 "
Area of details, (square miles)	19¼

Mr. F. R. Hassler aided in the field-work of this party.

Sub-Assistant Mechan is now preparing to return to Section IV.

Supplementary topography on Long Island, N. Y.—Portions of detail in two localities on Long Island were filled in by Sub-Assistant F. W. Dorr during the month of August. The additions made join with his map of Williamsburg and Green Point, and are designed to give symmetry to the engraved chart of New York harbor. These extend the topography along the New York and Jamaica turnpike, as far towards the interior of Long Island as the completed work north and south had been carried. The sheet worked on this season takes in part of the Flushing railroad and the Brooklyn reservoir.

Supplementary work was also filled in east of Rockaway, to include Hicks's Neck and the entrance called Hog Island inlet. The tract surveyed there is mostly marsh, and subject to changes along the shore, especially in the vicinity of the inlet named.

The following statistics comprise the aggregate of details added to the survey of Long Island:

Shore-line	7¼ miles.
Creeks	24 "
Marsh-line	11 "
Roads	45¼ "
Area, (square miles)	8

Sub-Assistant Dorr is about to proceed to Section VI to continue plane-table duty.

Soon after the opening of the present surveying year, Mr. Rockwell inked and sent to the archives his plane-table sheet of the east side of Harlem river, being part of the result of last year's work in the vicinity of New York. A sheet containing the topography of part of Brooklyn, the city of Williamsburg, and Green Point, has also been turned in by Sub-Assistant Dorr.

Hydrography of the Hudson river, N. Y.—The regular hydrography of the North river was taken up at Poughkeepsie on the 28th of July, and has been extended northward to Rhinebeck and Rondout, (Sketch No. 6.) The sheet containing the soundings represents about fifteen miles of the channel of the river. This work was done by the party of Lieut. Comg. C. M. Fauntleroy, U. S. N., Assistant Coast Survey, with the schooner Varina. The hydrography was discontinued for the season on the 17th of September, when arrangements were commenced preparatory to the return of the party to Section V.

Of the Hudson river work the following are the general statistics of the season in sounding:

Miles run	308
Angles determined	2,737
Number of soundings	14,827

The previous work executed by this party will be referred to under the head of Section V.

Twenty-four stations were used on the Hudson for hydrographic purposes, and the tides were observed at three stations by the hydrographic party while the soundings were in progress.

Lieut. Comg. Fauntleroy has turned in all the journals and records connected with the hydrography.

Hydrographic examination of False Hook and Cholera bank, New York bay.—On the return of the steamer Bibb to New York for repairs, after special duty in August last, the executive officer of that vessel, Mr. Robert Platt, proceeded, under special instructions, to make an examination of the vicinity of False Hook. The schooner Joseph Henry was used in this service, and the result has been returned by Mr. Platt in the form of a chart, accompanied by records of the soundings taken. An examination of the chart seems to confirm the conclusion which was presented in a special paper on the subject of changes at Sandy Hook, in Appendix No. 27 of my annual report for 1858.

The chart returned by Mr. Platt contains the following statistics:

Miles run in sounding	50
Angles determined	541
Casts of the lead	3,650

Cholera bank, which lies about fifteen miles eastward of the light-boat off Sandy Hook, was sounded by Mr. Platt, and the result sent to the office.

Lieut. Comg. Wilkinson in December last deposited in the office two sheets, showing the results of examinations made on the Battery shoal and on Diamond reef, (New York harbor,) with journals of the soundings. Before leaving that port for duty at the south he also determined and sent to the office a sketch showing the position of the Black spar buoy, No. 5, which now marks the northeast point of the shoal off Sandy Hook, and its former position to the westward and northward in thirty-six feet water. The depth at the present position of the buoy is twenty-nine feet. While making these determinations, Lieut. Comg. Wilkinson was accompanied by the master of the light-house tender Narragansett.

Magnetic observations.—The magnetic declination, dip, and intensity were determined in August and September by Assistant Charles A. Schott at the following stations on the southern coast of Long Island and sea-coast of New Jersey, viz: Sag Harbor, L. I.; Mount Prospect, (Brooklyn,) west base; (Fire island;) Barnegat light-house, N. J.; Long beach, (Little Egg Harbor;) and Absecom light-house, (Atlantic city, N. J.)

The instruments used and method of determining the elements have been described under the head of Section I, several stations in New England having been occupied by Mr. Schott, in addition to those here mentioned. He was assisted in the observations by Assistant A. S. Wadsworth. The results found at all the stations are given in Appendix No. 29.

In determining the dip at the stations in Section II, needles No. 1 and No. 2 were both used.

Tidal observations.—The self-registering tide-gauge at Governor's island, in New York harbor, which is one of the permanent tidal stations, has been kept in operation by Mr. R. T. Basset. Interruptions in the series during the winter were met by observing with an ordinary box-gauge at the Atlantic ferry dock in Brooklyn. The records of the year have been maintained with great regularity. The series of observations made at that station is now highly valuable, though occasionally interrupted by accidents which could not be foreseen.

SECTION III.

FROM CAPE HENLOPEN TO CAPE HENRY, INCLUDING THE COAST OF PART OF DELAWARE, THE COAST OF MARYLAND, AND PART OF THE COAST OF VIRGINIA.—(SKETCH C, No 8.)

The usual number of parties has been at work in this section, with the ordinary amount of progress. The chief work remaining is in the lower part of Chesapeake bay and the Potomac river, with some details of topography. The office-work has made very considerable progress in important charts during the year.

A short summary is here given of the operations in field and office, which will follow it in detail.

1. An examination of station-marks set for recognizing the points determined in the main triangulation of Chesapeake bay. Such of the marks as required attention were replaced.

2. The extension, a short distance above Nottingham, of the triangulation of the Patuxent river, Md.

3. Further progress in the triangulation of the Potomac river. The work now reaches from the entrance of the river to Britton's bay.

4. A topographical survey from the coast of Maryland and Virginia across to the head of Pocomoke sound, embracing the tract lying in the immediate vicinity of the boundary line between the two States.

5. Supplementary details of topography at the mouth of Elk river, Md., and plane-table work on the Patuxent and St. Mary's rivers.

6. The topography of the shores of North river completed, and that of the shores of Ware river nearly so. These are tributaries of Mobjack bay.

7. Hydrography of the Potomac river from its entrance upward to and including St. Clement's bay.

8. The series of tidal observations at the Washington navy yard, D. C., and at Old Point Comfort, have been continued with self-registering gauges.

In addition to the work of routine in this section, views of the vicinity of Cape Henry have been drawn, to accompany charts of the Chesapeake entrance.

Office-work.—Progress has been made in the drawing and engraving of coast map and chart No. 29, from Isle of Wight, Del., to Little Machipongo inlet, Va., and on Nos. 31, 33, 35, and 36, Chesapeake bay; in the engraving of No. 32, Chesapeake bay, from Magothy river to Hudson river, Md.; on the chart of the Rappahannock river; and in the drawing of chart No. 30, from Little Machipongo to Great Machipongo inlet; on that of the entrance to James river, and on general coast chart No. IV, from Cape May to Currituck sound. The drawings of the upper and lower, and the engraving of the lower sheet of a preliminary chart of the Patuxent river, have been completed, as also the drawing of the chart of St. Mary's river, Md., and the engraving of the preliminary chart of that river, has been continued. The plate of the map of York river, Va., has been completed, and additions made to the progress sketch.

Examination of stations.—At intervals in July and August, and while his party was employed in this section in plane-table work, Assistant G. D. Wise visited the primary and secondary stations in the lower part of Chesapeake bay. Most of them on that part of the bay shores were found secure, and at any that seemed to require further protection additional marks were placed. The primary point at Cape Charles had been destroyed, but some of the secondary stations near Cape Henry were found undisturbed.

Mr. Wise visited all the principal stations excepting "Rosemary," the party being unable to land in its vicinity in consequence of a storm that prevailed during the visit.

A note-book containing the results of his examination, with remarks appended to refer to each station, and sketches showing their positions and the manner of marking, has been furnished to the office by Mr. Wise.

Triangulation of the Patuxent river, Md.—A reach of the river extending about three miles above Nottingham, and which had not been included in the preliminary survey of the Patuxent, has been connected with that work by triangulation. This duty was executed by Assistant John Farley in April and May. Sub-Assistant S. A. Wainwright was attached to his party, and under the direction of Mr. Farley ran the shore-line of the river to the upper limit of the triangulation. The work of Mr. Wainwright joins at Nottingham with the preliminary survey made by Assistant Adams. The supplementary triangulation is shown on Sketch No. 8. Assistant Farley used the six-inch Gambey theodolite, C. S. No. 76.

The details of the work are as follows :

Stations occupied	8
Angles measured	28
Number of observations	752

The schooner Mason was used in this service.

Assistant Farley has turned in the computations resulting from his field-notes.

Triangulation of the Potomac river.—The party of Assistant Farley reached Piney Point on the 26th of October, and pushed the triangulation of the Potomac from its limit in that vicinity up the river to Blackstone island. Just below the island a chain of triangles was made to diverge from the main series, so as to include Britton's bay to its head at Leonardtown, on the Maryland side of the Potomac. On the south side of the river the triangulation was extended to Nomini cliffs, (Sketch No. 8.) The field-work was carried on until the 24th of December, and again prosecuted from the 24th of April until the 17th of June, a short interval of the latter period being employed in the supplementary work on the Patuxent.

Sub-Assistant Wainwright assisted Mr. Farley in the early part of the season, and subsequently made a shore-line survey of the lower side of the Potomac, opposite to Piney Point.

The schooner Mason was left in charge of Mr. Wainwright when the triangulation was discontinued in June.

A summary of the statistics of work is appended:

Stations occupied	17
Angles measured	70
Number of observations	1,306
Area of triangulation, (square miles)	60

The observations were made with the six-inch Gambey theodolite, No. 76.

Topography between Chincoteague bay and Pocomoke sound.—A plane-table party, in charge of Sub-Assistant C. T. Iardella, commenced on the 18th of July, near Snead signal, (Sketch No. 8,) and made a survey westward to connect with the topography of the shores of the Pocomoke river. The sheet containing the work embraces the tract at the head of the peninsula between the Atlantic ocean and the waters of Chesapeake bay.

Mr. T. C. Bowie aided in this survey. The field-work was continued until the 18th of August, when Mr. Bowie and all the hands in the party, and in the following week Sub-Assistant Iardella himself, were taken ill with fever, and compelled to discontinue the topography. The portions done are on two sheets, which now comprise the following details:

Shore-line	$9\frac{1}{2}$	miles.
Creeks	$25\frac{3}{4}$	"
Roads	$35\frac{1}{4}$	"
Area, (square miles)	24	

The working season at the south was employed by Mr. Iardella, in Section VI. He is now preparing to resume plane-table duty there.

Supplementary topography at the mouth of Elk river, Md.—Assistant Hull Adams left Baltimore on the 8th of June, and filled in a small space which had not been reached in the general topography of Chesapeake bay. The part referred to lies on the south side of the mouth of Elk river, (Sketch No. 8,) between Captain John's creek and Pond's creek, and embraces about five miles of the river shore. This work completes the detailed topography of the upper sheet of the bay.

Mr. J. L. Tilghman accompanied Assistant Adams as aid. The party returned to Baltimore on the 23d of June with the schooner Guthrie.

The following are statistics of the additional topography:

Shore-line	9½ miles.
Area of plane-table work, (square miles)	12

The supplementary work was done on a separate plane-table sheet, which has been filed in the office.

Mr. Adams had been previously employed in other surveys in this section. On closing the work on Elk river he took up duty in Section I.

Topography of the Patuxent river, Md.—The shore-line survey of the main body of this river has been completed by Assistant Adams, and the sheet returned will furnish the material required for the finished map. Resuming work early in May at Town Point, a little above Benedict, (Sketch No. 8,) Mr. Adams executed the details in topography embraced on both shores of the Patuxent as far down as the mouth of St. Leonard's creek, or nearly fifteen miles below Benedict. His plane-table sheet includes also the mouths of Indian creek, Trent Hall, Washington, Coles's, and Battle creek, and the mouths of other streams which enter in the same reach of the Patuxent.

The plane-table party returned to Baltimore early in June with the schooner Guthrie, and then took up supplementary work in the upper part of this section, as already referred to.

Assistant Adams was aided in the field by Mr. J. L. Tilghman.

The following summary of statistics is taken from the plane-table sheet:

Miles of shore-line surveyed	56
Area, in square miles	60

Sub-Assistant S. A. Wainwright, while attached to the triangulation party of Assistant Farley, extended the shore-line survey of the Patuxent about three miles above Nottingham, the previous limit of the preliminary work. This supplementary survey was made in May.

Topography of the Potomac river, Md.—On the Maryland side of the Potomac, above and below the entrance to the St. Mary's river, plane-table work has been extended so as to complete the survey of the north shore of the Potomac, between Point Lookout, on Chesapeake bay, and Piney Point. This topography is supplementary to that of St. Mary's river, and was executed by Assistant Adams, between the 2d of November and the 26th of December, with a party in the schooner Guthrie. Some few subsidiary points being necessary for carrying the work to the head of the St. Mary's, Sub-Assistant Charles Ferguson was detailed to extend the triangulation to the desired limit, and furnish points for plane-table use.

The topographical work done by Assistant Adams this season on the Potomac comprises that part of its north shore which lies between Cornfield harbor and Kit's Point, (see Sketch No. 8,) and includes the banks of Potter's creek, Jones's creek, and Smith's creek and its branches. The last named is a considerable dependency of the Potomac, and is stated as being a very convenient harbor for vessels in rough weather.

Proceeding upwards, Mr. Adams added details at several points, and completed the map of St. Mary's river. The chart of that arm of the Potomac, in a preliminary form, accompanied my last annual report.

Above the mouth of the St. Mary's, both shores of St. George's creek were surveyed to the distance of two miles, the south shore being formed by the northern side of St. George's island. From the upper limit of work in that vicinity the shore of the Potomac, including the "Narrows," was traced as far as Piney Point light-house.

By reason of the severity of the season the plane-table work was discontinued at the date before mentioned, and the party returned with the vessel to Baltimore.

The following summary of statistics is taken from the report of Assistant Adams:

Shore-line surveyed	47½ miles.
Roads	3 "
Area of topography, (square miles)	32

The sheet containing this supplementary work is now at the office.

In the early part of summer Sub-Assistant Wainwright traced forty-one miles of shore-line on the south side of the Potomac, below Sandy Point. This work includes the entrances of the Coan and Yeocomico rivers.

The two parties have now resumed work in continuation of that just stated; Mr. Adams and Mr. Wainwright executing the detailed survey on opposi'e shores of the Potomac, and using the same vessel.

Topography of the North aud Ware rivers, Va.—The plane-table work outstanding on the western side of Chesapeake bay was resumed on the 26th of June by a party under charge of Assistant G. D. Wise, who was aided in the field by Mr. Oscar Hinrichs. The details executed fall within the limits of a sheet which had been projected by Assistant John Seib a short time previous to his death, in December, 1859.

Assistant Wise continued personally in charge of the party until near the end of July, but was then compelled to return to Baltimore in consequence of illness. The work after that period was conducted by Mr. Hinrichs, who was also attacked with fever, but remained in the field until the 22d of September, at which date the schooner Howell Cobb returned with the party to Baltimore.

Sketch No. 8 shows, in a general way, the progress made in the survey of the two branches of Mobjack bay, named in the head of this notice. Along the shores of Ware river the topography was extended about three miles, both being included on the plane-table sheet. The survey of the banks of the North river was completed to a point about six miles above its entrance into Chesapeake bay. A summary of statistics is appended:

Shore-line traced	65 miles.
Roads	68 "
Area, (square miles)	25

The schooner Howell Cobb had been previously employed this season by the party of Mr. Wise in Section VII, and is now preparing to return to the south. Mr. Hinrichs has been reassigned to duty in the party of Assistant Bolles in Section V.

Hydrography of the Potomac river.—The regular hydrography of the Potomac was commenced in the middle of July last, the St. Mary's river and part only of the bed of the main river in its immediate vicinity having been sounded out last year. Commander W. T. Muse, U. S. N., Assistant Coast Survey, with a party in the steamer Hetzel, took up the work on the lower side of the Potomac, at its junction with Chesapeake bay, and sounded along the southern shore, so as to connect with his survey of last season, and then extended the general hydrography of the river upwards to a station above St. Clement's bay. That branch of the Potomac, as also the one below it, known as Britton's bay, both making in from the Maryland side of the river, were sounded out. On the Virginia side the sheet includes the arms called the Coan and Yeocomico rivers, (Sketch No. 8.)

The hydrography of the Potomac has thus far kept pace with the triangulation, and both of these operations are yet in advance of the detailed topography.

The statistics of work done by the party in the Hetzel are as follows:

Miles run	843
Angles measured	1,856
Number of soundings	42,269

Commander Muse continued the hydrography until the 22d of October, and then returned with the party to Baltimore. Since the opening of the present year he has deposited in the archives three sheets containing his surveys of parts of the Patuxent, St. Mary's, and James rivers. A fourth, containing the soundings of Monic bay and Manokin, Wicomico, and Annemessex rivers, has also been turned in.

Magnetic observations.—Preparatory to taking up a series of observations at several points in Sections I and II, notices of which have been made under their respective heads, Assistant Charles A. Schott determined, at the Coast Survey office, the constants of the instruments to be used in his observations. He also made observations there for the magnetic declination, dip, and intensity, by methods and with instruments which have been described under Section I. Appendix No. 29 contains the results found at all the stations.

Tidal observations.—During the present year the self-registering tide-gauge at the Washington navy yard, D. C., has given excellent results under the care of Mr. J. W. Donn, aid in the Tidal Division of the Coast Survey office. As heretofore, every facility for keeping the instrument in steady operation has been afforded by Commander Dahlgren and the other officers in charge of the ordnance department of the yard.

Observations have been continued at Old Point Comfort, Va., with the self-registering gauge, under the charge of Mr. M. C. King. This series extends through a period of sixteen years, but the continuity has at times been broken by accidents. Of late years the observations have been kept with greater regularity.

SECTION IV.

FROM CAPE HENRY TO CAPE FEAR, INCLUDING THE COAST OF PART OF VIRGINIA AND OF PART OF NORTH CAROLINA.—(SKETCH D, No. 10.)

Two parties have been engaged in this section, and the results of their work were somewhat affected by the hurricane of the 29th of April, which was of extraordinary violence. The changes of this coast from the encroachment of the ocean I have several times called attention to, and am always impressed with the dangerous progress which the ocean is making whenever I take up the records of our parties on its outer coast.

The following operations have been in progress in field and office:

1. The triangulation of the southwestern part of Pamplico sound, N. C.
2. A plane-table survey of the beach forming the Atlantic coast and eastern shore of Pamplico sound, between Cape Hatteras and a station near Ocracoke inlet, N. C., and supplementary work at Oregon inlet.
3. A hydrographic reconnaissance in the upper waters of Currituck sound, ranging from Coanjock bay to Weir Point, on the North river, N. C.
4. A line of soundings run from Cape Henry to Cape Lookout, traversing the general off-shore hydrography.

A view has been drawn of the vicinity of Cape Hatteras for the off-shore chart No. V.

Office-work.—The engraving of coast maps and charts Nos. 40 and 41, Albemarle sound, has been brought up with the field-work; additions have been made on the progress sketch of the section, and miscellaneous work done in retouching and correcting plates. Progress has been made in the drawing of general coast chart No. VI, from Ocracoke inlet to Charleston; on coast map and chart No. 37, from Cape Henry to Currituck sound; on Nos. 46 and 47, from Cape Lookout to Barren inlet, N. C., and on preliminary sea-coast charts Nos. 11 and 12, from Cape Hatteras to Cape Fear.

Triangulation of Pamplico sound, N. C.—As stated in my last report, the preliminaries for this work were arranged and executed last season by Captain T. J. Cram, U. S. Topographical Engineers, Assistant in the Coast Survey. His party, in the schooner Guthrie, was again at its working ground on the 25th of October, 1859. Assistant A. S. Wadsworth accompanied the party, and, under the direction of Captain Cram, made most of the angular measurements. The portion of the triangulation completed lies at the southwestern end of the sound. Six stations were occupied in that quarter, and one at the northeastern end, connecting directly with the Bodies' island base. The angles were measured with the C. S. theodolite No. 18. Sketch No. 10 shows the triangles so far completed by the observations.

The intention of occupying three stations in addition to the number just mentioned was frustrated by the very violent storm which raged in Pamplico sound on the 29th of April. Its force was such as to destroy the high tripod signals at Cedar island and Pea island, the heavy timbers of which they were made being broken so as not to admit of repairs. At Cedar island the water, raised by the action of the wind, swept directly across the site of the signal and undermined it. The signal at Roanoke marshes was also overturned, but re-erected afterwards from the same material. The station points, being marked well below the surface of the ground, were not lost by the overflow of water in the storm alluded to. It is stated by Capt. Cram, as the result of general inquiry, that no gale in Pamplico sound since that of August, 1839, has equalled it in fury.

The damage done to the signals, involving the labor of renewing several of them, will delay the completion of the main triangulation, which Capt. Cram had estimated as being quite practicable by the end of next season.

In the course of the present year eight signals of the first order were erected. The progress made in the details of the triangulation is shown by the following abstract:

Primary stations occupied	7
Signals observed on	15
Angles measured	33
Number of observations	4,708
Area, in square miles	385

The field-work was discontinued on the 15th of May.

Capt. Cram has provided materials for erecting the signals necessary for a secondary triangulation within the limits of the primary work. The reconnaissance for subsidiary stations, to include points on the shores of the sound for the plane-table survey, has been in progress, and the execution of the details will, if found practicable, be pushed forward with the main triangulation.

The original record of horizontal angles measured this season has been duplicated and placed in the archives of the office.

Coast topography north and south of Cape Hatteras, N. C.—Towards the end of the working season at the south, and after concluding more extended duty in this section, Sub-Assistant John Mechan completed the survey of a gap left in the topography below Bodies' island. The interval referred to was about four miles in length, and occurred at the junction of sheets left unfinished by the death of Assistant J. J. S. Hassler. The sheets were projected so as to connect, when finished, at Oregon inlet.

On the 19th of January Mr. Mechan took up the detailed survey of the coast of North Carolina at Cape Hatteras, (see Sketch No. 10,) and pushed it southward and westward to within seven miles of Ocracoke light-house, closing for the season on the 4th of May at "Great Swash." The stretch of main coast embraced is rather more than twenty-one miles. On the peninsula beach, which ranges from the cape southward to Hatteras inlet, and separates the ocean from Pamplico sound, the topography proved to be quite intricate. "From Durant's Point to within a mile or so of the inlet the beach averages a mile and a half in width and is thickly wooded, intersected by marshes, creeks, and ponds, and studded with small, arable patches and vegetable gardens. The ground above Durant's Point, for a distance of about two miles, is low in profile and only half a mile wide. The winds have divested it of both trees and sand dunes, and it is thus rendered liable to inundation as well from the ocean as from the water of Pamplico sound."

The beach on the side towards Pamplico sound is thickly settled, the houses being mostly the dwellings of pilots. Below Hatteras inlet, Sub-Assistant Mechan surveyed the greater part of the insular beach, which runs towards Ocracoke, forming the outer coast line of North

Carolina as far as Great Swash, and to the same extent on the inside the shore of the sound. He also determined and laid down in position on the plane-table sheet the shoal and islet known as "Legged Lump," which lie in Pamplico sound at the distance of nearly five miles W. by N. from Hatteras inlet.

Mr. F. R. Hassler aided in the field-work of this party.

The following statistics, taken from the report of Mr. Mechan, include the supplementary topography executed at Oregon inlet:

Shore-line surveyed	69	miles.
Roads surveyed	19¼	"
Area of topography, (square miles)	16	

Connected with a remark which has been quoted from the report of Sub-Assistant Mechan, in reference to the narrow neck of land or rather beach, above Durant's Point, it is further observed: "The same cause (action of the wind and sea) is steadily diminishing the area of the cape, and in this vicinity, generally, the Atlantic and sound waters are gaining on the land. Since 1853 a breadth of about three-quarters of a mile of the beach at Cape Hatteras, abreast of the light-house, has been washed away. The district, however, between the cape and the settlement below it, called 'Trent,' presents very considerable resistance to the waters. The average width of the peninsula there is two miles, and it is densely wooded with different kinds of oak, pine, maple, bay, beech, and dwarf palmetto. In contour the ground is comparatively bold, and although the soil is mostly of sand, except where the numerously interspersed sedge swamps occur, it is yet remarkably compact.

"The small inlet which lay open immediately below Hatteras inlet in 1857 has lately closed up, but the main inlet remains almost unchanged."

Special service executed by the party in charge of Sub-Assistant Mechan, in the upper part of this section, will be noticed under the head of hydrography.

All the plane-table sheets brought from the field have been inked and registered in the Coast Survey office.

Off-shore soundings.—On the return passage of the steamer Bibb from service at the south, Lieut. Comg. Alexander Murray, U. S. N., Assistant Coast Survey, carried soundings coastwise and in deep water on a continuous line from the parallel of Cape Lookout to a position near Cape Henry. These soundings will serve as a verification in part of the general off-shore hydrography of the upper part of the section. The direction of the line run is marked on Sketch No. 10. One thousand and forty casts were made with the lead in a run of about four hundred miles.

The steamer Bibb reached New York on the 11th of June, and was there refitted for other service.

Notice will be taken of the previous work of this party, in describing the operations of the year, in the next two sections. One of the lines run by the Bibb, in returning from Florida, was extended to the vicinity of Cape Lookout, as will be seen by the Progress Sketch No. 10.

Before resuming duty in the present year Lieut. Comg. Murray sent to the office eighteen volumes comprising the hydrographic records of the work done by his party between Bogue inlet and New River inlet, in the surveying season of 1858–'59. These were accompanied, as customary, by a smooth journal of all the notes.

Hydrographic reconnaissance.—In the upper waters of Currituck sound, N. C., the party of Sub-Assistant Mechan sounded out the space designated as Coanjock bay, and also several miles of the course of North river, which extends from the head of the sound across the boundary between Virginia and North Carolina, and forms the upper part of the water communication between Chesapeake bay and Albemarle sound. A channel of about fourteen miles in length is represented by the sheet containing the soundings. The reconnaissance was carried up the North river to the mouth of Blackwater creek.

This duty was performed by the plane-table party in December, before taking up the regular operations in this section, as already explained. Mr. F. R. Hassler was attached to the party and aided in the work by determining the stations selected for boat soundings with the theodolite.

The following is a synopsis from the record kept by Sub-Assistant Mechan:

Miles run in sounding	34
Sextant angles taken	151
Theodolite angles from shore-stations	117
Number of casts with the lead	3,441

The level of the water of the sound was recorded daily during the month spent in this work. The journals containing them were turned in promptly, together with the note-books of the soundings, and the results were plotted at the office.

SECTION V.

FROM CAPE FEAR TO ST. MARY'S RIVER, INCLUDING PART OF THE COAST OF NORTH CAROLINA, AND THE COAST OF SOUTH CAROLINA ND GEORGIA.—(SKETCH E, No. 13.)

The survey has been in full activity in this section from three centres—one at the north, on the coast of North Carolina; one in the middle, on the coast of South Carolina; and one at the south, on the coast of Georgia. In another season it will present a continuous triangulation from Winyah bay to the St. John's river.

A new channel into Sapelo sound has been developed, and some changes found at Ossabaw since the survey of the Topographical Engineers in 1846.

Both off and in shore hydrography have made excellent progress in the section.

The work will be described under the following heads:

1. Primary and secondary triangulation and topography of the coast of North Carolina, west of Shallotte inlet, completing the land operations between Cape Fear and the State boundary at Little river.

2. An extension of the primary triangulation of the coast of South Carolina to Port Royal sound, and its connection with the Edisto base, and with the triangulation of St. Helena sound.

3. The triangulation of the Morgan, Coosaw, and Beaufort rivers, which connect the waters of St. Helena and Port Royal sounds.

4. Triangulation of the coast of Georgia, from Altamaha sound southward and westward. This work crosses St. Simon's entrance, and includes Jekyl and St. Andrew's sound, and a part of Cumberland island.

5. The filling in of details of the plane-table survey between Port Royal sound and Savannah river. The topography includes Hilton Head island and the shores of Calibogue sound and its branches.

6. Progress in the plane-table survey of Wassaw sound, and extension of the topography of Ossabaw island. The work on Ossabaw island forms part of the material of the survey of St. Catharine's sound.

7. Off-shore hydrography between Charleston harbor and Fernandina; a partial survey of Maffitt's channel, and a complete hydrographic survey of Morgan, Coosaw, and upper part of Beaufort river, S. C. The off-shore work is supplementary to the system of lines run last year.

8. A complete hydrographic survey of Ossabaw sound, including the bar and approaches, and the principal tributaries of the sound.

9. The hydrography of Altamaha sound, Ga., in connection with in-shore soundings abreast of St. Simon's island. The work was extended upwards to Mud river, and includes also Hampton river.

10. Tidal observations continued at the custom-house wharf, Charleston, S. C.

Office-work.—Preliminary charts of Port Royal entrance and Bull's bay, S. C., and Sapelo

sound, Ga., have been drawn and engraved, and additions made to the chart of Charleston harbor, and to the progress sketch of the section. The drawing of the chart of St. Simon's sound, Brunswick harbor, and Turtle river, has been completed and its engraving commenced. Progress has been made in the drawing of general coast chart No. VII, from Winyah bay to St. John's river; on that of coast map and chart No. 48, from Barren inlet, N. C., to Lockwood's Folly inlet, N. C.; on Nos. 53 and 54, from Rattlesnake shoals to Fripp's inlet, S. C., and on the chart of Ossabaw sound; and the engraving of preliminary sea-coast chart No. 14, from Cape Romain to Savannah, has been continued.

Coast triangulation and topography between Shallotte inlet and Little river, N. C.—The party of Assistant C. P. Bolles took the field on the 14th of December, and completed the details of the main and secondary triangulation from Shallotte inlet westward and southward to Little river. The plane-table work was resumed at the same time by Mr. O. Hinrichs, the aid in the party, and was extended from Tubb's inlet westward to the limit of the triangulation. The additional triangles are laid down on Sketch No. 13. Abreast of Tubb's inlet the stations corresponding to the northern angles of the main series of triangles are in the immediate vicinity of the road which leads from Wilmington, N. C., to Georgetown, S. C. In measuring the angles Mr. Bolles used the six-inch Brunner theodolite, C. S. No. 67.

This work completes the land operations of the survey of the coast of North Carolina between Cape Fear and the southern boundary. At every step it has been carried on only by determined effort, the sides of all or most of the principal triangles requiring to be opened and cleared of the obstacles which otherwise would interpose in the lines of sight. An aggregate length of eleven miles and a half was prepared in this way for observing during the present year. The following synopsis gives the general particulars of the triangulation:

Signals erected	23
Stations occupied, (primary)	3
Angles measured	7
Number of observations	606

The plane-table work done by Mr. Hinrichs is represented by the following statistics:

Coast-line surveyed	10.14 miles.
Shore-line of creeks	66.56 "
Marsh-line	27.25 "

Primary triangulation southward from the Edisto base, S. C.—The scheme for extending the main triangulation of the coast of South Carolina below the primary base on Edisto island, and for connecting that work with the secondary triangulation of the lower part of St. Helena sound, having been fully matured, and its execution provided for by the preparation of lines and the erection of signals last season, Assistant C. O. Boutelle commenced the measurement of horizontal angles in the early part of January. Six primary stations were occupied in succession, viz: West base, (Edisto island;) Aiken; Ashepoo; Coffin; Baptist church, (Beaufort, S. C.;) and Port Royal. The position last mentioned is on the east bank of Beaufort river, and near its entrance into Port Royal sound. The entire series is shown on Sketch No. 13. The instrument used in determining the primary angles was the ten-inch theodolite, C. S. No. 43. In order to clear the lines of sight from intervening objects, tripods with high scaffolds were required at all the stations. Excepting that in Beaufort, in which instance the tower of the Baptist church furnished the desired elevation, the structures were forty-five feet in height, and were erected by the party. The device of setting screens so as to protect the theodolite scaffold from the effect of prevailing winds was again employed by Mr. Boutelle, their use in the primary work on the coast of Maine, as mentioned in my last annual report, having fully proved their utility.

It will be seen by reference to the progress sketch (No. 13) that the primary triangulation is

now complete between Charleston harbor and Port Royal sound. To the southward of its present limit some of the stations have been selected for extending the work to the Savannah river.

At the line "Morgan——Otter island" the primary series was connected with the secondary triangulation which covers St. Helena sound. The extension of the secondary and tertiary work within the limits of the main triangulation will be referred to under the next head. The smaller chain which passes down the coast of South Carolina, and is now continuous from Bull's bay to Tybee entrance, was also connected with the principal series of triangles by the line "Coffin——Otter island," as may be seen by the progress sketch.

The schooner Petrel was used by the party of Mr. Boutelle in this section.

Notwithstanding the disadvantage under which the main triangulation was carried on south of the Edisto base, arising from the great elevation of the platforms found to be necessary in observing with the theodolite, the greatest error in a single angle, as given by the measures, is only twenty-eight hundredths of a second.

The primary work was closed for the season at Port Royal station on the 24th of April.

A duplicate of the record of horizontal angles measured in the work connecting with the Edisto base has been received from Mr. Boutelle.

Triangulation of the Morgan, Coosaw, and Beaufort rivers, S. C.—These rivers connect the waters of St. Helena and Port Royal sounds, and are partly within the limits noticed under the preceding head.

After completing the triangulation of the upper part of St. Helena sound, Assistant Boutelle projected and measured the angles of a series of triangles, including the Coosaw river, as high up as Port Royal Ferry, (Sketch No. 13,) and, from an intermediate point in the chain, completed the triangulation of Beaufort river by pushing that work southward to the city of Beaufort, where it meets the completed work of the lower part of the river. The triangulations which pass separately up these waters unite at the Brickyard, on the Coosaw.

"This work was rendered exceedingly difficult by the high, dense wood which lies just north of Beaufort. The trees formed a complete barrier to vision from the primary station in Beaufort, although it is seventy feet above the level of the city. Other points of wood presented obstacles at every turn of the river, and cutting was required on all the lines but two. At Pigeon Point a flag on a tall pine was found the best expedient, and another signal of the same kind was used on approaching the Coosaw, in order to avoid extensive cutting in joining the triangulation of the two rivers."

The Morgan river and Parrott creek were included by Mr. Boutelle in the triangulation going southward from St. Helena sound.

At the river stations the angles were measured with the ten-inch theodolite, C. S. No. 43, and the eight-inch instrument, C. S. No. 24. The mode of observing was that usually employed in the triangulation of this section. Each set of six repetitions with the theodolite is a mean of three direct and three observations with the instrument reversed.

Messrs. C. H. Boyd and C. B. Boutelle were attached as aids to the triangulation party. The schooner Petrel, which had been in use for transportation, was laid up at Charleston on the 3d of May.

Frequent allusion has been made in previous notices of work in this section to the development of the Inland passage, as it is called, which ranges along the coast of South Carolina and Georgia, behind the sea islands. Another link of this important line of communication has been developed this season by the joint labors of the field and hydrographic parties on duty in this vicinity. In the course of his triangulation Assistant Boutelle furnished the points necessary for sounding out the Coosaw and Morgan rivers, and the upper part of Beaufort river, from its junction with the Coosaw to the city of Beaufort. The following is an extract from his preliminary report made in March last: "That part of Coosaw river lying above Coosaw

island, and between the island and the junction of Beaufort river with Coosaw river, has been supposed too shallow for the steamers that formerly passed between Charleston and Savannah, and they have often grounded there at very low tides." "In beating down the river last week I found a continuous channel which will probably give fifteen feet at mean low water over the whole bed of rocks which forms the bottom of the river, where six and seven feet was supposed to be the best water."

The passage referred to is taken by steamers running south of Charleston by the inland route. Its development will be more particularly referred to, under the head of hydrography, before closing this chapter.

The field operations were stopped for the season at the end of April. Mr. Boutelle reported in person at the Coast Survey office on his way northward, and then took up duty in Section II. The following is a summary of statistics of the primary and secondary triangulation executed between the rivers connected with St. Helena and Port Royal sounds:

Stations occupied	31
Angles measured	401
Signals observed on	358
Number of observations	6,980

Triangulation of Jekyl and St. Andrew's sounds, Ga.—Sub-Assistant F. P. Webber, with a party in the schooner Hassler, took up work near Darien on the 5th of December, and completed the secondary triangulation marked on Sketch No. 13, which includes the Inland passage between Altamaha and St. Simon's sounds. At Turtle River entrance his work connects with two of the triangles measured by Assistant Longfellow in the survey of St. Simon's sound, and from thence the coast series was extended southward and westward quite across Jekyl and St. Andrew's sounds, including also the Great and Little Satilla rivers, and through the Inland passage, behind Cumberland island, to a station within twelve miles of the mouth of St. Mary's river.

On comparing, by computation, the length of the side "Brunswick Point——Cedar Hammock," (See Sketch No. 13,) which connects with the Sapelo preliminary base through twenty-six triangles, and also with the preliminary base at St. Simon's sound, the difference in length, as derived from the independent measurements, was nine-tenths of a metre.

Mr. Webber used the ten-inch Gambey theodolite, C. S. No. 63, and the six-inch Brunner, C. S. No. 52, and in the course of his triangulation determined the exact positions of seventy-four points. The statistics of the work are appended in the usual form:

Signals erected	55
Stations occupied	26
Objects observed on	358
Angles measured	355
Number of observations	3,354

Mr. Julius Kincheloe aided Sub-Assistant Webber in the field, and also in computing from the recorded notes.

The vessel used reached New York, on her return from duty in this section, on the 12th of April, and was afterwards employed in Section I.

Sub-Assistant Webber thus refers to the impediments met in pushing the triangulation southward, between St. Simon's island and the main land of Geogia: "The Inland passage, through which it was necessary to carry the triangulation, is about three miles wide, and a branch of the fresh water of the Altamaha river has caused the grass to grow to the height of twelve to fifteen feet. The hard land being on a level with the marsh, I was obliged to build four tripod signals with scaffolds, for observing with the theodolite. One of these was twenty-five feet

high, and the others each sixteen feet. As the work advanced to the southward we were able to progress faster."

A duplicated record of the horizontal angles measured between Altamaha river and Cumberland island has been received from Mr. Webber, and placed in the office, with his descriptions of the stations occupied for carrying on the triangulation.

Coast topography from Port Royal entrance, S. C., to Savannah river, Ga.—The details of this work, following the shore-line survey of last year, have been completed by Mr. Cleveland Rockwell, to whom the duty was assigned after the death of Assistant John Seib. Field-service was resumed on the 23d of January, and closed on the 22d of May.

The topography is contained on two sheets, and embraces Hilton Head island, the entire shores of Calibogue sound and its branches, including also the inland passage which connects it with Port Royal sound and the shores of Cooper and May rivers, the whole of Dawfuskie, Turtle, Pine, and Bull islands, and part of Pinckney's island. At the junction of Mackay's and May river the survey takes in a small portion of the main land of South Carolina, the plane-table work heretofore reported being wholly confined to the belt of sea islands which ranges along the southern coast. The limits of the topography may be seen on Sketch No. 13.

Having been associated with Assistant Seib in the preliminary survey, Mr. Rockwell's knowledge of the ground enabled him to push on the work, and, with the advantage of weather favorable upon the whole for field operations, to make a large return of material. The following are the statistics:

Shore-line	190 miles.
Roads	64 "
Area, in square miles	90

Mr. Rockwell's party used the schooner Bailey for work in this section. The vessel returned to New York early in June. Arrangements were made at the outset of the surveying year for the completion of the plane-table work between Port Royal entrance and Savannah river, but the movements of the party were delayed in consequence of the sudden death of Assistant Seib, which occurred on the 23d of December, at Washington. I have elsewhere in this report alluded to the faithful labors of that able topographer, whose industry and patience merit a lasting remembrance in connection with the plane-table survey of this and other sections of the Atlantic coast.

Topography of Wassaw and St. Catharine's sounds, Ga.—The plane-table survey of Wassaw sound was begun on the 24th of March by Sub-Assistant H. S. Du Val, with a party in the schooner Meredith. About five miles of the outer shore of Little Tybee island, on the north side of the entrance, and as much of the outside of Wassaw island, were traced, and the shore-line given to the hydrographic party then working in Ossabaw sound. The survey of Ossabaw island had been resumed with a view of completing the map of St. Catharine's sound within the season if practicable. Mr. Du Val, after joining his sheet with the topography of the upper part of the island, executed by Assistant Harrison in 1858, continued the work southward to within four miles of the point at the entrance of St. Catharine's sound.

On Ossabaw island the party worked under unusual difficulties from the opening of the year until after the middle of March. These were in part due to the continued rains in January, but to a greater extent arose from the nature of the surface features of the interior of the island, the marshes, creeks, and woods being so interspersed as to make it a matter of great difficulty to pass from point to point with the plane-table.

The two localities of work referred to in this notice are shown on Sketch No. 13.

Sub-Assistant Du Val was aided in the field by Mr. J. D. Bradford.

The following is a summary of progress made by this party:

Sea shore-line surveyed	5 miles.
Shore-line of navigable creeks	36 "
Area of details, (square miles)	15

The part of Ossabaw island not yet surveyed is reported as being comparatively easy of access, and of such a nature as to admit of closing the plane-table survey of St. Catharine's sound readily in the coming winter.

Off-shore hydrography, coast of South Carolina and Georgia.—Lieut. Comg. J. P. Bankhead, U. S. N., Assistant in the Coast Survey, occupied two intervals of the working season in running with the schooner Crawford additional lines of soundings between Charleston harbor and Fernandina. Their extent and direction will be seen by comparing the lines traced on Sketch No. 13 with those on the corresponding sketch of my previous annual report. The soundings were made in April and June, and extended from the coast to the limits of the Gulf Stream. Two of the lines were run coastwise between Charleston light-house and St. Simon's entrance. The statistics are appended:

Miles run	895
Soundings	1,071

An extract from the report of Lieut. Comg. Bankhead will be given in my remarks on the Gulf Stream.

In addition to the work just referred to, three lines of soundings were started from positions off Fernandina (Sketch No. 13) and carried northward in the direction of the coast of Georgia and South Carolina to Charleston, one of them being so run as to converge in two parts at Tybee entrance. From Charleston a line was carried in the direction of the coast to Cape Lookout.

These soundings were made by the hydrographic party in the steamer Bibb, under the charge of Lieut. Comg. Alex'r Murray, U. S. N., Assistant Coast Survey, and after concluding duty for the season in Section VI. Further mention will be made of its previous operations.

The statistics of off-shore soundings are as follows:

Miles run	590
Casts of the lead	1,459

Resurvey of Maffitt's channel, Charleston harbor.—At the request of the harbor commissioners of Charleston, made opportunely while the schooner Crawford was at that port with the party of Lieut. Comg. Bankhead, a partial examination was undertaken by that officer in order to determine the condition of the channel surveyed by Lieut. J. N. Maffitt in 1850. The portion sounded out extends from the buoy on the end of the jettee to the black buoy in the channel. A tide-gauge was set up at Fort Sumter for the reduction of the soundings, but after recording a short series of observations it was unfortunately swept away by a heavy gale, preventing the establishment of a bench-mark for the references desirable in comparing the results with those given by the former surveys of the channel. The soundings were begun on the 9th, and concluded on the 11th of May.

In his report, made in advance of the plotting of his hydrographic sheet, Lieut. Comg. Bankhead remarks: "That the channel has narrowed since the dredge-boat was discontinued is an undoubted fact, but to what extent can, at present, be only a matter of surmise."

Hydrography of the Coosaw, Morgan, and Beaufort rivers, S. C.—These rivers, intermediate between, and connecting the waters of St. Helena and Port Royal sounds, were thoroughly examined and sounded out by the party of Lieut. Comg. Bankhead in May, during an interval of the working period which was employed in two other localities of this section. In the Coosaw, the hydrography was joined with that of St. Helena sound, and was extended up to the junction of Beaufort river, and down that river to the city of Beaufort. The hydrography

of the lower part of Beaufort river was executed, in connection with that of Port Royal sound, in 1855, by Lieut. Comg. Maffitt.

Lieut. Comg. Bankhead sounded out the channel of Morgan river, and that of its branch, Parott's creek, which connects the Morgan with Coosaw river in passing around Morgan island.

In connection with the river hydrography, the tides were observed for a full lunation for the accurate reduction of soundings. The following are the statistics of general work:

Miles run	463
Angles determined	1,652
Casts of the lead	26,488
Area sounded, (square miles)	12

This hydrography was executed with the schooner Crawford. The courses of the rivers sounded are marked on Sketch No. 13.

I have already adverted, under another head, to the general interests which may inure from the development of the inland passage along the southern coast.

Hydrography of Ossabaw sound, Ga., and its approaches.—This hydrographic survey was commenced and completed within the present season by the party of Lieut. Comg. C. M. Fauntleroy, U. S. N., Assistant in the Coast Survey, working with the schooner Varina and steam-tender Fire Fly. The soundings in the approaches were carried out nine miles from shore into eight fathoms water, and extend over a space of about the same length abreast of the entrance, including in the coastwise range of the sheet three miles of the shore of Great Wassaw island, on the north side of the entrance, and about two miles and a half of the outer shore of Ossabaw island, as will be seen by referring to the progress sketch (No. 13.)

A full development was made of the outer bar, and of the channel leading into the sound. In allusion to that part of his work, Lieut. Comg. Fauntleroy thus reports: "The channel is narrow, and the entrance leading into the sound is nearly six miles to the southward of it. It can be approached with confidence, as the soundings shoal gradually from eight to three and a quarter fathoms, which can be carried in until the north point of Ossabaw island bears west, where the water deepens to six and seven fathoms. Thence on, it shoals until within a mile and a half of the north point of Ossabaw, nearly abreast of the point of bare shoal, where the channel is suddenly obstructed by a belt extending inward for nearly two miles, and over that only fourteen feet can be carried at low-water to deeper water, and a safe anchorage inside. The anchorage is off the west point of Raccoon island, close to, in six and seven fathoms, sticky bottom." Other remarks taken from the same report relative to the character of the sound and its dependencies will be found in the Appendix (No. 12.)

Besides the bar, entrance, and body of the sound, the hydrographic operations of the party in the Varina embraced the survey of the Ogeechee river to a distance of four miles from its mouth, and the mouth of the inland passage leading from it southward; the hydrography of the Vernon river up to Montgomery, and that of the lower part of its tributary, the Little Ogeechee, with portions also of the Romerly Marsh passage and Wassaw creek. At the Romerly marshes the work was connected with soundings made by Lieut. Comg. J. N. Maffit in 1855. A preliminary chart of Ossabaw sound accompanies this report, as Sketch No. 14.

Tidal observations were made from February 9th until April 25th by the hydrographic party at Camp creek, and in the Ogeechee, opposite to the Florida passage, from the 9th until the 25th of April.

The currents were observed in the usual way at four stations while the soundings were in progress.

The hydrographic survey of Ossabaw sound is based on the topography executed by Assistant A. M. Harrison in 1858. An extract from the report of Lieut. Comg. Fauntleroy shows that the effect of the ocean on the land had become quite noticeable in the short period which has

elapsed since the completion of the plane-table survey. He says: "The seaward face of Ossabaw island has certainly undergone considerable change of feature since that portion of the shore-line embraced in my projection was executed. The triangulation point, '*N. Ossabaw island No.* 2,' has washed away since the commencement of our survey, and the spot is now marked by a large tripod erected by my party."

On the morning of the 21st of February the Russian bark *Vesta* ran on the north breaker at Ossabaw entrance and was wrecked. Her officers and crew were received and sheltered for the night in the Varina, and by the co-operation of Lieut. Comg. Fauntleroy and his party the cargo and stores of the vessel were ultimately saved to the owners. These services have been acknowledged in suitable terms, addressed to the chief of the party, by the Russian vice-consul at Savannah.

The particulars of the hydrographic work at Ossabaw are summed up as follows in the report:

Hydrographic signals determined	55
Theodolite angles observed	1,235
Sextant angles observed	3,147
Miles run in sounding	958½
Number of soundings	55,568
Area, (in square miles)	110

Part of the shore-line traced this season by Sub-Assistant Du Val was furnished to the hydrographic party. Progress in the work during March and April was much hindered by the causes referred to in the notice already taken of the plane-table survey in the vicinity of Ossabaw sound.

The season at the north was occupied by the party in the Varina in extending the hydrography of the Hudson river in Section II.

Hydrography of Altamaha sound and adjacent coast of Georgia.—This work was executed by the party of Lieut. Comg. Bankhead with the schooner Crawford, who employed the months of February, March, and April in this part of the section. The work includes the hydrography of the lower part of Altamaha sound, and that of the coast abreast of St. Simon's island. It embraces also six miles of the channel of Hampton river. The sheet containing the soundings is yet unfinished, the seaward limit so far reached going only four miles from shore to seaward. In Altamaha sound the hydrography was extended three miles upward from the entrance, or to the junction of Mud river, which forms a link of the inland passage, leading behind St. Simon's island.

Lieut. Comg. Bankhead remarks as follows on the character of the approaches to this part of the coast of Georgia: "The hydrography of the Altamaha was very difficult, owing to the great number of sand bars and shoals which extend immediately off the coast to the distance of three or four miles. At times, too, it was dangerous, as involving the necessity of sending the sounding boats that distance from the schooner, but, by watching the weather closely, all accidents were avoided."

The following is a summary of the statistics:

Miles run	623
Angles determined	2,203
Soundings	39,812
Area sounded, (square miles)	48

In reference to the sound itself, Lieut. Comg. Bankhead observes: "The Altamaha being subject at certain times to freshets, the bar can never be made available for any but vessels of light draught, as the channel is constantly shifting, and at times has not more than five feet depth at low water."

"The shore cannot be approached with safety nearer than three and a half miles anywhere between St. Simon's and Doboy entrances."

The work abreast of St. Simon's island was discontinued on the 14th of April, the party in the Crawford then taking up the off-shore hydrography already mentioned in this chapter.

During the latter part of summer, and until the end of the working season at the north, Lieut. Comg. Bankhead was engaged in hydrographic duty in Section I.

While employed in the hydrography off St. Simon's entrance, Georgia, the schooner Crawford very narrowly escaped destruction on the morning of the 13th of June by a water spout. The spray from it fell on the deck of the vessel, but fortunately a flaw from the whirlwind at the same time shot the schooner ahead, causing her taffrail barely to clear the body of the rushing column.

Tidal observations.—The permanent self-registering tide-gauge at the custom-house wharf in Charleston, S. C., has worked with regularity throughout the year, though under difficulties which will require some ingenuity to overcome in order to preserve the series unbroken. Experiments for this purpose are now in progress. The registers of the year have been steadily kept up by the observer, Mr. W. R. Herron.

SECTION VI.

FROM ST. MARY'S RIVER TO ST. JOSEPH'S BAY, INCLUDING THE EASTERN AND PART OF THE WESTERN COAST OF FLORIDA, WITH THE REEFS AND KEYS.—(SKETCH F, Nos. 15 and 16.)

This section has advanced remarkably well during the season. The work has been going on from four centres—St. Augustine, in the north; Indian River inlet, in the middle of the eastern coast of the peninsula; the keys near the Cape Sable base, at the south; and Charlotte harbor, on the western side of the peninsula. The line across the peninsula has also made good progress. One of the largest season's work of topography in the Coast Survey, by a single party, was executed at Charlotte harbor.

The operations will be stated in the following order:

1. Progress in the air-line triangulation from Waldo station westward to Gainsville, Fla.

2. Triangulation north and south of St. Augustine harbor. This work connects with the coast triangulation going south of St. John's river, and extends southward, along the coast of Florida, to Matanzas inlet.

3. Triangulation completed, and plane-table survey made of Indian River inlet, Fla. A hydrographic reconnaissance was made in connection with this work.

4. A connection across the waters of Chatham bay, Fla., by triangulation, from Card's sound to the limit of the reef triangulation at Pigeon key. This completes the preliminary work on the main line of the keys between Cape Florida and Key West.

5. Further progress nearly completing the triangulation of Charlotte harbor, Fla. The work done includes the upper part of the harbor.

6. A complete topographical survey of the shores of St. Augustine harbor, including the city, the coast approaches, and the shores of the San Sebastian, the Matanzas, and the North river adjacent to the harbor.

7. Progress in the plane-table survey of Charlotte harbor, nearly completing it. This survey includes the lower parts of Myakka river and Peas creek, Fla.

8. St. Augustine harbor and its approaches thoroughly sounded, and lines run coastwise to traverse the off-shore hydrography of the section. In the course of this work a four-fathom bank was discovered off the coast of Florida, northeast of Indian River inlet.

9. The hydrography of the Florida reef, extended from Grassy key, northward and eastward to Lower Matacumba. Soundings continued in the same direction will complete the outside hydrography of the reef at Key Rodriguez.

10. Magnetic observations recorded by photography at Key West. These are designed to be comparable with a series obtained in Section I.

11. Tidal observations continued at Fort Clinch and at Tortugas. This last station has been selected as a point of reference for the observations made on the reef and on the Gulf coast of the Florida peninsula.

Views of the vicinity of Key West and other keys have been drawn for the charts of the Florida reef.

Office-work.—The drawing has been completed and the engraving continued of coast map and chart No. 68, from Key Biscayne to Carysfort reef, and No. 71, from Bay Pine key to Boca Grande key. A chart of St. Augustine harbor has been drawn and progress made in its engraving, as also in the drawing and engraving of general coast chart No. X, from Cape Florida to Cape Sable. The drawing of coast map and chart No. 58, from St. Mary's river to St. John's river; Nos. 69 and 70, from Garden key to Bay Pine key, (Florida reef,) and No. 74, from Lower Matecumbe key to Cape Sable, has been continued. The progress sketches have received additions, and diagrams have been drawn and engraved to illustrate the results of explorations in the Gulf Stream.

Triangulation across the Florida peninsula.—The preliminaries for the measurement of angles to extend this work beyond the limit already reached were resumed, in January last, near Waldo, a point on the line of the Florida railroad. These, as in several past seasons, include, in addition to the selection of suitable points and the putting up of signals, the cutting and clearing of lines constituting the sides of the triangles. The work has been continued under the general charge of Captain M. L. Smith, U. S. Topographical Engineers, Assistant in the Coast Survey, and has advanced to the vicinity of Gainsville, in its course between Fernandina and Cedar Keys. The details of the scheme were executed by a party under the immediate direction of Lieut. R. G. Cole, U. S. A., Assistant Coast Survey. Lieut. O. D. Greene, U. S. A., joined the party on the 14th of February, and co-operated efficiently in assisting Lieut. Cole.

The expense and labor of opening all the lines of sight in prosecuting the work southward and westward from Fernandina suggested the expedient of throwing one side of the entire series of triangles for the remaining distance on the cleared line of the railroad to Cedar Keys.

This plan was adopted at the outset of the present season. The chain of triangles prepared by Lieut. Cole, for measurement, will extend the triangulation twenty-seven miles, and is projected (Sketch No. 15) so as to make the stretches of the railroad correspond, as far as practicable, with the southern sides of the triangles. Field operations were continued until the 12th of June. Lines making in the aggregate about sixty-nine miles, and forming five complete triangles, were cleared, and two other triangles were partly prepared for observing with the theodolite. The length just stated is exclusive of the triangle side, running in the direction to Cedar Keys. Eight signals were commenced, and the construction of six of them completed, before the close of the season.

Capt. Smith has it in view to take up, during the present autumn, and complete the measurement of angles as far as the cutting already done has prepared lines, before the main party again takes the field for opening others below Gainsville.

The nature of the surface of the northern part of the Florida peninsula, in its bearing on the progress of the air-line triangulation, was referred to in my annual reports for 1857 and 1859.

Triangulation north and south of St. Augustine, Fla.—A connection has been made between the triangulation going south along the coast of Florida, from St. John's river entrance, and that executed last year from St. Augustine harbor northward. The gap then left and now closed by the connecting triangles extends about eight miles from the source of North river. The junction between the two chains of work was made in the line "Tam Smith —— Sulana," (Sketch No. 15,) which is about twenty-three miles north of St. Augustine.

This work was executed by the party of Sub-Assistant Benjamin Huger, jr., between the 28th of November and the 16th of April. The entire course of the North river is included in the triangulation.

The triangulation south of St. Augustine was resumed, a scheme for its extension along the coast having been perfected by Mr. Huger in the course of the last surveying season. In following it out Sub-Assistant W. H. Dennis, who was attached to the party and in charge of it while Mr. Huger was disabled by sickness, carried forward and completed a range of triangles, including about ten miles of the coast south of the entrance to St. Augustine, and within that space the course of the Matanzas river. The operations of the party were closed on the 6th of May. A summary of the statistics of field-work is given below:

Angles measured	60
Signals observed on	21
Number of observations	1,002
Area of triangles, (square miles)	22

The angles were measured with the six-inch Würdemann theodolite, C. S. No. 83. Mr. Huger has forwarded to the office the records of the triangulation.

Triangulation at Indian River inlet, Fla.—On making an examination previous to resuming work in the vicinity, Sub-Assistant Charles Ferguson found the preliminary base which had been measured in the season of 1858–'59 by Sub-Assistant Sullivan, and marked by stone blocks, in good order, and the tripods and signals then erected still standing, with but one exception. This was at once reset, and the ends of the base were occupied as stations. The triangulation was taken up on the 7th of February, and continued jointly with the topography, until the 12th of March. Six secondary signals were built for plane-table work along the line of Indian river. These average twenty-five feet in height, and are so arranged as to admit of being occupied with the theodolite. One of the signals used in the triangulation is fifty feet high. The positions of all of them are marked on Sketch No. 15.

"The difficulty in carrying on the triangulation arises from the character of the islands bordering on the ocean. They are covered with a dense growth of mangrove, oak, and palmetto, and the ground rises gradually from the sea-beach to the middle, where the hills abruptly end, leaving a swamp of palmetto underbrush, decayed logs, roots, and stumps of trees, on the western side of the islands."

The lines observed on by Sub-Assistant Ferguson connect the outer coast with the main land of Florida abreast of Indian River inlet, and extend the triangulation north and south about seven miles to a station five miles above Fort Capron. All the angles were measured with the six-inch Gambey theodolite, C. S. No. 65. The statistics are given below in the usual form:

Stations occupied	11
Angles determined	44
Number of observations	2,584
Area of triangulation, (square miles)	24

Mr. Horace Anderson aided in the field-work of this party.

The instruments and camp equipage used were transported in the schooner Benjamin Peirce.

In adjusting his scheme of triangles, Mr. Ferguson selected stations eligible for extending the work either north or south from its present limits.

The records of the triangulation have been duplicated and deposited in the archives, with descriptions of the station-marks left for purposes of future reference. Sub-Assistant Sullivan has completed from the original, and turned in with it, a duplicate of the record of notes made in measuring the preliminary base at Indian River inlet.

Triangulation of Barnes's sound, Fla.—A triangulation has been made by Assistant G. A.

Fairfield connecting that leading from the Key Biscayne base, through Card's sound, (Sketch No. 16,) with the work done on the inner keys, and with the triangulation passing across Florida bay, from the general line of keys to the primary base on Cape Sable. The space included in his work is known as Chatham bay. It forms the eastern part of Barnes's sound, and lies southward and westward between Shell key and Pigeon key, being bounded on the east mainly by the inner shore of Key Largo.

Sub-Assistant P. C. F. West assisted in the triangulation. The work was taken up on the 7th of March, and prosecuted until the 26th of May.

The depth in the channel of Tavernier creek not admitting of the passage of the schooner Caswell, which was used by the party, Assistant Fairfield took the vessel through a pass about five miles below Pigeon Key, and moved up along the inside of the reef as far as the draught would allow. A camp was found necessary in making the angular measurements from Pigeon key, and also for occupying the station on Pie key, the point at which the triangulation connects with the work done last year by Lieutenant Seward. Having gone as far as practicable in that quarter, Mr. Fairfield took the schooner to the north side of Key Rodriguez, and transported the material for signals by a boat through Tavernier creek, opening at the same time a road across the narrow part of Key Largo. This plan greatly facilitated the future operations of the party. One of the boats being left on the inside of the key, the party thus had means for returning to the vessel, which lay at anchor outside of the reef.

The statistics of the triangulation are as follows:

Signals erected	15
Stations occupied	11
Angles measured	54
Observations with the theodolite	1,748

The instruments used were the ten-inch Gambey No. 15, and the six-inch Brunner theodolite, C. S. No. 66.

In his report Mr. Fairfield commends the efficiency shown by Sub-Assistant West, and also specially refers to the ready co-operation of Sailing-master Budd in the erection of signals and scaffolds required at the theodolite stations.

The schooner Caswell reached Baltimore on the 13th of June, and was laid up during the summer.

Assistant Fairfield has sent to the office his record of the horizontal angles measured, and descriptions of the station-marks.

Triangulation of Charlotte harbor, Fla.—The operations conducted this season by Lieutenant W. R. Terrill, U. S. A., Assistant in the Coast Survey, very nearly completed the triangulation of Charlotte harbor and its dependencies, only the narrow pass between Pine island and the main land of Florida yet requiring points to be determined for the plane-table survey.

Lieutenant Terrill joined with his work of last season at Boca Grande, and also at a station on the north end of Pine island, and from thence northward executed the triangulation shown on Sketch No. 15. It includes all the upper part of the harbor and a portion of Peas creek, which empties from the eastward into its northern extremity. Along the Gulf shore the stations occupied this year reach nearly nine miles above Boca Grande, leaving in that direction only a few points necessary for the complete development of the approaches.

The stations previously used, and with which it was necessary to connect, having been marked with care, were easily recognized, although the signals had gone down in the two violent gales of October 28 and November 13, 1859. Some delay was occasioned in resetting them; but the observations were taken up on the 22d of December, and steadily prosecuted until the 20th of March. The angles were measured with the ten-inch theodolite, Gambey No. 81. The topography was provided for by points furnished as the triangulation advanced.

Lieutenant Terrill was assisted in the field by Lieutenant George Bell, U. S. A., Assistant,

and by Sub-Assistant W. S. Edwards. Mr. J. L. Tilghman was attached to the party as aid, but early in February reported, in accordance with previous instructions, for duty in the plane-table party of Sub-Assistant Finney.

The progress in the triangulation is shown in the appended synopsis:

Number of signals erected	40
Stations occupied	30
Objects observed on	42
Angles measured	113
Number of observations	6,580
Extent of triangulation	30 miles.
Area in square miles	120

Lieutenant Terrell commends the zeal and efficiency of the assistants who were associated with him in work, and also makes special mention of aid cordially rendered by Sub-Assistant Iardella, who conducted the plane-table party. The schooner Bowditch was used in carrying on the triangulation.

In making arrangements for continuing the survey of the western side of the Florida peninsula, such means as are available will be applied to the hydrography of Charlotte harbor, so as to provide for the issue of a chart with the least delay possible. To meet in some measure now the desired end, Lieutenant Terrill has communicated sailing directions for entering it by the principal pass, Boca Grande, (see Appendix No. 31,) with remarks in reference to the capacity of the channel inside, and the character and extent of the existing shoals. Some remarks on the coast features between Charlotte harbor and Tampa bay are given in the same appendix. These furnish the results of a reconnaissance through Sarasota bay on the return of the vessel from Tampa with materials required in the work of Charlotte harbor. The reconnaissance was made at the outset of the season.

The schooner Bowditch reached New York, on her return from the south, on the 9th of April, and is now refitting for the completion of the preliminary work in which she was previously employed.

An abstract of the record of horizontal angles determined in the preliminary work at Charlotte harbor, and the usual field computation, have been furnished by Lieutenant Terrill. He has also filed at the office the original notes, and descriptions of the signals and stations.

Topography of St. Augustine harbor, Fla.—A complete plane-table survey of the harbor, shores, and city of St. Augustine and the adjacent coast, including also several miles of the banks along the courses of the North and Matanzas rivers, has been made by the party of Sub-Assistant F. W. Dorr. The work is contained on two sheets, one of which represents the entrance, the city, and the northern part of Anastatia island, portions of the Matanzas and San Sebastian rivers in the vicinity of the harbor, the entire shores of the harbor, and the lower part of North river. Its limits, as also those of the second, which extends the survey along the eastern coast of Florida, and takes in also a part of North river, are laid down on Sketch No. 15. On the Atlantic shore the work was carried about sixteen miles north of the entrance to St. Augustine, and four miles southward of it. Both banks of the North river were traced to a distance of nearly eight miles above its mouth; and the banks of its tributary, the Guano river, seven and a half miles from its entrance into the main stream. For the most part, the wood line, or edge of the pine barren, was taken as the western boundary of the plane-table work.

This survey was made between the 1st of December and the 21st of March.

Sub-Assistant Dorr was aided in the field by Messrs McLane Tilton, and H. W. Bache, and employed the schooner Dana for transportation.

The following is a summary of the statistics of field-work:

Shore-line surveyed	86 miles.
Creeks surveyed	135 "
Marsh-line	79 "
Roads	40½ "
Area in square miles	40

The shore-line given on Sketch No. 17 was reduced from the two plane-table sheets of Mr. Dorr. The execution of the hydrography, which appears on the preliminary chart of the harbor and approaches, will be referred to under that head.

The survey of St. Augustine was founded on the triangulation made last year by Sub-Assistant Huger.

I have placed in the Appendix (No. 30) some extracts from the report of Sub-Assistant Dorr, having reference to the topographical features of this part of the coast of Florida.

The two plane-table sheets of the survey of St. Augustine harbor and North river were inked by Mr. Dorr immediately after his return from the section, and are now on file in the Coast Survey office. He was engaged during the summer in plane-table duty in Section II.

Topography of Indian River inlet, Fla.—Within the limits of his own triangulation of this season, Sub-Assistant Ferguson made a plane-table survey of the eastern coast of Florida within a range of seven miles above and below Indian River inlet. The limits of the sheet containing it are marked on Sketch No. 15, which shows the progress made at this and other localities in the section.

The survey at the inlet includes the entrances and the adjacent shoals and mouths of the passes leading from them.

Mr. Ferguson also made preliminary soundings through the Fort Pierce channel, and determined in position the buoys and stakes from the entrance southward into the main river, which is about a mile and a half south of Fort Capron.

The topography embraces, in addition to numerous small keys, one of the large mangrove islands near the main inlet, the village at Fort Capron, and the west bank of Indian river, from the village to a point two miles below it. The statistics are thus given in the field report:

Shore-line surveyed	20 miles.
Shoals	8¾ "
Roads	1 "
Area covered by topography, (square miles)	10

In reference to the capacity of the Fort Pierce channel and characteristics of this part of the coast of Florida Mr. Ferguson observes: "This channel is the widest and has about six feet water in the deepest part at high tide It is filled with sand bars and oyster beds, which render the navigation difficult and dangerous for vessels drawing over three feet of water. The other inlets to the river are hardly navigable, even at high tide, by fishing boats, as they are mostly blocked up by shoals and sand bars. One of these was sounded out while the party was employed in the section.

"Indian river is from three quarters to a mile wide. Its western shore is marshy, with occasional hummocks, and about half a mile from the shore-line runs a ridge, covered with pine and palmetto trees. The height of this ridge was determined by the theodolite, and found to be fifty-two feet above low tide at '*Ridge*' signal. Its general direction is about N.NW., and nearly parallel with the water-line.

"There are two channels over the bar at Indian River inlet. The southern one opens during a series of northerly gales, and fills up when the wind is in a contrary direction. Three buoys of timber, with granite blocks attached to them, were placed in this channel by the plane-table party. The buoys were marked with white crosses at their tops.

"There has not been, at any time during the season, more than three feet of water in either of the bar channels at low tide, and not often six feet at the highest. The ordinary rise of the tide is about two feet."

Special care was taken by Mr. Ferguson in tracing the shoals inside of the bar. As far as practicable, they were occupied with the plane-table at low water, and when this could not be done, signals were put up and determined from other fixed points.

The plane-table work was begun in February, and stopped for the season on the 20th of April; the schooner Benjamin Peirce being then laid up after her return to New York.

Mr. H. Anderson, the aid of the party, on reporting at the Coast Survey office, was assigned to duty in Section X.

Sub-Assistant Ferguson's plane-table sheet, and that containing the soundings made by his party, are now at the Coast Survey office. After its completion he took up field duty in Section I.

Topography of Charlotte harbor, Fla.—It has already been remarked that the points requisite for this plane-table survey were determined as the triangulation of the season went forward. While these preliminaries were in progress Sub-Assistant C. T. Iardella, who was assigned with a party in the schooner Agassiz for pushing on the topography, employed the time in co-operating with Assistant Fairfield in the triangulation of Chatham bay, notice of which has been taken in this chapter.

Plane-table work was resumed at Charlotte harbor on the 13th of January, Mr. Iardella joining his first sheet at Boca Grande (see Sketch No. 15) with one executed last year by Sub-Assistant Ferguson. On the western or Gulf side, Gasparilla and Boca Nueva keys, with many detached and broken patches peculiar to that part of the coast of Florida, were surveyed within the range of fifteen miles between Boca Grande and Bocilla Pass, and the inner shore-line from Bocilla Pass to Aguado key.

"This part of the peninsula is cut into hundreds of small keys, which are entirely covered with water at spring tides, and some of them at ordinary low water. Between the keys the water is so shallow that at times it is impossible to pass a boat from key to key, without dragging it through the mud."

Three other sheets, projected by Sub-Assistant Iardella, embrace all the main shore of the upper part of Charlotte harbor north of Pine island; several miles of the course of the Myakka river, one of its tributaries, and fifteen miles of the course of Peas creek, another. Both of these streams make in at the north end of the bay. The last mentioned is stated to be navigable from its entrance to Whiting's camp, a distance of twenty miles, for vessels drawing five feet. Its banks are high and covered with pine trees of good size.

The general character of the western shore of the harbor, at its upper part, is the same as that referred to as descriptive of the opposite or Gulf coast. In outline it is very irregular and marked by innumerable little creeks and lagoons.

The plane-table work followed the triangulation of Lieut. Terrill, with whom Mr. Iardella co-operated as occasion required. On closing for the season only a few minor details remained to complete the survey inside of the harbor. As the work is now well advanced, it is proposed to take up the hydrography this winter.

The schooner Agassiz was despatched for New York on the 2d of April, and was laid up there on the 20th. Preparations are now making for her return to this section.

The progress made in the plane-table work is shown in the following statistics:

Shore-line surveyed	295 miles.
Area in square miles	89

On his return from the Gulf coast, Mr. Iardella occupied the first part of the summer in inking his sheets, and then took up plane-table work in Section III.

Hydrography of St. Augustine harbor and its approaches, Fla.—This service was performed by a party in the schooner Arago, placed temporarily in charge of Lieut. Comg. Alexander Murray, U. S. N., Assistant Coast Survey, for that duty. Soundings were commenced on the 23d of February, and closed with the completion of the survey on the 10th of April. Two sheets have been returned, one of which shows the harbor abreast of the city of St. Augustine, with eight miles and a half of the course and channel of the North river, and rather more than five miles of the course of the Matanzas, and also the part of its tributary, the St. Sebastian, adjacent to the city. On the second sheet, are shown the entrance to the harbor, the bar, and the coast hydrography, ranging about eight miles north and south of the entrance, and extending six miles seaward. The preliminary chart resulting from this work is given as No. 17 of the sketches which accompany this report. A synopsis of the statistics of soundings is thus given on the original sheets:

Number of positions used	1,273
Miles run in sounding	312
Angles taken	2,472
Number of soundings	17,233

The plane-table party of Sub-Assistant Dorr furnished shore-line, and such points as were needed by the hydrographic party were determined by Sub-Assistant Huger.

On the completion of the survey, Lieut. Comg. Murray returned to Charleston, and resumed command of the steamer Bibb, transferring the Arago at the same time to the party of Lieut. Comg. W. Ronckendorff.

The journals of soundings and angles made in the survey of St. Augustine harbor, together with a smooth register compiled from the original notes, have been received from Lieut. Comg. Murray. He has also forwarded to the office specimens of the bottom taken in sounding.

The party in the steamer Bibb was employed during part of the autumn in Section II.

Off-shore soundings.—From two positions off Fernandina (Sketch No. 15) lines of soundings were extended by Lieut. Comg. Murray in running with the steamer Bibb southward and westward towards St. Augustine, and thence southward, in general conformity with the trend of the eastern coast of Florida, to positions north and south of Indian River inlet. In that vicinity the lines were deflected and carried quite across the current of the Gulf Stream, and will be again alluded to in remarks under that head.

At the termination of one of his lines, about fifteen miles northeast of Indian River inlet, Lieut. Comg. Murray found a shoal with only four fathoms, and distant from the main coast of Florida about ten nautical miles.

This off-shore work was performed after the completion of the survey of St. Augustine harbor, and after the return to Charleston and transfer of the party from the vessel used in that service. The following statistics are taken from the returned chart of off-shore work:

Miles run	336
Soundings	1,963

Traverse lines, similar to those here mentioned, have been described in referring to the occupation of this party in Section IV and Section V. Towards the end of the present season the steamer Bibb was employed in Section II.

Hydrography of the Florida reef.—On the outer side of the general line of keys the hydrography of the Florida reef has been continued from the vicinity of Coffin's Patches (Sketch No. 16) in a direction northward and eastward to Lower Matacumba key. The soundings were extended broad off about six miles, and are conformable with the completed portions of the reef hydrography.

This duty was executed by the party of Lieut. Comg. John Wilkinson, U. S. N., Assistant Coast Survey, with the steamer Corwin. The work was taken up on the 16th of January, and

closed on the 14th of April, special service being then assigned to the same party in Section VIII.

Tidal observations were made regularly at Tom's harbor while the reef hydrography was in progress. The general statistics are given in the following summary:

Signals established	4
Miles run in sounding	900
Angles determined	4,604
Number of soundings	35,845
Area in square miles	84

The work here noticed connects near Coffin's Patches, with a hydrographic sheet completed last season by Lieut. Comg. T. A. Craven, and leaves a reach of rather more than twenty miles to be sounded between Rodriguez bank and Lower Matacumba key in order to complete the general chart of the Florida reef.

In the course of his duty this season, Lieut. Comg. Wilkinson made a careful examination of Tennessee shoal, which lies about four nautical miles S. by E. (by compass) from the east end of Long key. The shoal (so-called) was found to be more properly a group of shoals, the outer and most dangerous (one as being at an elbow of the reef, and near its edge) having only twelve feet water.

About a mile and a quarter from the outer shore of Grassy key the position of a sunken wreck was determined and marked by the party in the Corwin. The obstruction lies in twelve feet water on the northern edge of the Hawk channel, and bears south, (by compass,) distant about two miles from the middle of the key. I have given in the Appendix (No. 14) a copy of my communication to the department, with extracts from the report of Lieut. Comg. Wilkinson relative to these dangers.

Reference will be made, under another head, to the incidental advantage afforded of testing, by a short run of the vessel, the new form of sounding apparatus devised by Professor Trowbridge. The trials of the apparatus were made in the middle of March. After the return of the steamer Corwin to Key West, Lieut. Comg. Wilkinson, on being applied to by the agent of underwriters, went to the assistance of the American ship *Sarah G. Hyde*, and found her water-logged and unmanageable, about thirty miles to the westward of the Marquesas. The vessel was towed by the Corwin into Key West harbor.

Under the heads Gulf Stream and Section VIII, reference will be made to the subsequent labors of this party.

Magnetic observations at Key West, Fla.—A station has been established at Key West for the purpose of obtaining for a considerable period a constant record of the magnetic variations. The instruments employed are made self-registering by the application of photography, according to the plan devised by Mr. Charles Brooke, of London. Those now in use at Key West were obtained through the co-operation of the secretary of the Smithsonian Institution, and the observations were made in the same connection. The use of a wooden building on the grounds of Fort Taylor was procured from the Engineer Department for a temporary observatory.

The instruments at the station were mounted and put in operation by Professor W. P. Trowbridge, Assistant. Mr. Samuel Walker aided in that service.

The advantage of the photographic method for obtaining a continuous record of the variations of the magnet, as regards both economy and accuracy, has been fully demonstrated. A single observer, to prepare and renew the photographic sheets, to keep the lamps in order, and to have general oversight of the operations, accomplishes, by this method, the work of several persons. The method is well known, but will be here referred to in brief. The magnets are suspended in the ordinary manner, each having a small mirror attached to it, which partakes of its angular motion. A lamp kept constantly burning is so placed that the light falls on the

mirror, and from it is reflected to a cylinder placed at some distance from the magnet. The cylinder is covered neatly by a sheet of paper rendered highly sensitive to the light, and is made to revolve once in twenty-four hours by means of ordinary clock-work. The angular motions of the magnet, whether caused by the usual changes of the magnetism of the earth, or by unusual disturbances, are thus traced upon the paper, with a record of the time of their occurrence. Since the 1st of March of the present year continuous records have been obtained in this way.

In connection with the differential observations others have been made monthly for the absolute values of the magnetic declination, dip, and intensity at Key West. In these a set of portable instruments was used by Mr. Walker, who made the determination for February, March, April, May, and June. The continuation of the series since June have been in charge of Mr. G. D. Allen, of Key West.

Tidal observations.—The series of observations at Fort Clinch, near Fernandina, Amelia island, Fla., has been kept up continuously by Mr. J. A. Walker with one of the Saxton self-registering tide-gauges.

At Tortugas the series has been continued with a self-registering instrument by Mr. H. Benners. This important station has been selected as a permanent one in order to have a standard of reference for facilitating the investigation of the laws of the tides observed along the Florida reef and within the Gulf of Mexico. The observations now extend through several years, and have already furnished data for obtaining many valuable results.

It having been found impracticable to trace out the anomalies of the tides of the Gulf of Mexico from the detached and comparatively short series of observations hitherto made, the plan has been adopted, as referred to in my last annual report, of occupying a chain of stations along the Florida keys and Gulf coast, and conducting the operations so as to make the results obtained for each place comparable with the others through those given by the standard station of reference at Tortugas. The observations at each of the stations have been, generally, extended to a full year, and hence are minutely comparable with each other. They will thus furnish data for following the changes of the different tide waves step by step in their advance along the coast. In pursuing this plan three sets of stations have been successively occupied, and those at which the observations are yet in progress will extend the chain to Isle Dernière, west of the mouths of the Mississippi river. Self-registering tide-gauges have been used in executing the scheme here alluded to. These were under the general charge of Mr. Gustavus Würdemann, a faithful and experienced observer, until the time of his death, which took place late in the last surveying year. He was succeeded by Mr. A. C. Mitchell, who is now, with the aid of competent observers, employed in extending the chain of stations to the westward, as will be detailed in chapter VIII.

F STREAM.

Explorations similar to those heretofore made in the current of the Gulf Stream have been continued this year in the vicinity of the Tortugas. From thence a line of soundings was run southwest about seventy-five miles, by Lieut. Comg. John Wilkinson, U. S. N., Assistant Coast Survey, in the steamer Corwin, and from that limit taken southeast to the coast of Cuba. Ten positions were determined in depth, and at each the temperature of the water was noted at the surface, and at ten, twenty, thirty, fifty, one hundred, and one hundred and fifty fathoms.

Lieut. Comg. Alex. Murray, U. S. N., Assistant, in the steamer Bibb, ran, in June last, two lines from Gilberts' bar, on the eastern coast of the peninsula of Florida, between Indian river and Jupiter inlet, across to the Bahama banks, one line on a course north of east and the other southeast. Of these Professor Trowbridge says: "The first section commences about twenty-five miles from the coast. The depths obtained on this line furnish an approximate section of the bottom, in which one of the ridges parallel to the coast before discovered further

north, and indicated also in the Cape Florida section, distinctly appears. It occurs about thirty-five miles from the coast on the line of the section. The temperature observations are not sufficient in number to construct a diagram of the section all the way across.

"The next section, however, gives better results, though the temperatures were not taken often enough below fifty fathoms. The number of stations occupied was ten, the bottom being reached at each station.

"In the diagram representing the change of temperature with depth, it is necessary to connect the temperature at fifty fathoms with the bottom temperature by the form of curve which experience has established, as there are no intermediate temperatures. The diagrams representing the change of temperature across the stream exhibit two bands of cold water besides the cold wall, the latter feature being a marked one. It occurs about eleven miles from the coast.

"This section seems to confirm fully the conclusions arrived at from the Cape Florida section, that the bands of the Gulf Stream have their origin near the latter section. It will be observed that the section of the bottom on the second line of Lieut. Comg. Murray, from Gilbert's bar southeast, does not exhibit in a marked manner the ridges which undoubtedly exist there, while the temperatures indicate them distinctly. The explanation of this may be that the ridges here have a moderate elevation which will require more frequent soundings for their detection, while, at the same time, they may bear the same relation to the total depth (which is small) that the same ridges further north bear to the depths in those regions, and the forcing up of the cold polar current beneath is apparent in using the thermometer, even though the elevations are small. That they exist, however, the diagrams leave no room to doubt."

Both of the sections run from Gilbert's bar are shown on Sketch No. 22.

The new method of sounding described in my last annual report has been successfully tested by Professor W. P. Trowbridge, Assistant, who took passage for the purpose on board the steamer Corwin, and made the run near the Tortugas already alluded to. The results of the experiments made justify the belief that for sounding in a rapid current, or in very deep water, the method proposed by Assistant Trowbridge will prove more successful than any other.

While employed in the off-shore hydrography between Charleston and Fernandina, Lieut. Comg. Bankhead made temperature observations between the coast and the western limits of the Stream. The following remark taken from his report applies more particularly to the lateral influence exerted between Fernandina and Savannah, in still weather, by the great current in its progress northward from the Straits of Florida. Lieut. Comg. Bankhead says: "On three separate occasions, when in eighteen to twenty fathoms water, and far removed, as I supposed, from its influence, I have experienced a current of three miles an hour setting to the northward and eastward, and that during good weather, and when no violent gales had occurred to affect the body of the stream. The general set of the current over the whole of that section of the coast is northerly, as is always shown in running lines parallel to the shore by the difference between the true and the computed positions of the vessel employed in sounding."

The temperature observations made this season by Lieut. Comg. Wilkinson seem to indicate that some position between the Tortugas and Cape San Antonio is the point of junction of two distinct currents coming eastward, one around the cape, and the other from the Gulf of Mexico, and passing thence on as the Gulf Stream through the Straits of Florida.

SECTION VII.

FROM ST. JOSEPH'S BAY TO MOBILE BAY, INCLUDING PART OF THE WESTERN COAST OF FLORIDA AND THE COAST OF ALABAMA.—(SKETCH G, No. 25.)

The survey in this section has been in full activity, and the increased experience of the assistants has told notably in the quantity of work executed. The triangulation has nearly reached the southern limit of the section from the Cedar Keys centre, and is continuous from Ocilla river westward to Cape San Blas. The topography has kept pace with it, and important additions have been made to the hydrography.

A synopsis from the detailed statements of progress is here given, and will be followed by the notices at length:

1. Difference of longitude determined by telegraph between Apalachicola, Fla., Eufaula, Ala., and Macon, Ga., and observations made for latitude, azimuth, and the magnetic elements. The longitude determinations connect at Macon with a series which is now continuous from the northeastern boundary of the United States to New Orleans.

2. An extension to the entrance of St. Joseph's bay of the triangulation on the western side of the Florida peninsula from Bayport.

3. A triangulation east and west of St. Mark's harbor, completing the connection between the survey of Ocilla river entrance and that of St. George's sound, Fla., and triangulation of St. Vincent's sound completed westward to Cape San Blas.

4. The triangulation and plane-table survey of Maria de Galvez and East bays completed, and progress made nearly completing the preliminary survey of Blackwater bay. The work embracing these waters connects with the survey of Pensacola harbor, Fla.

5. A preliminary base measured, and triangulation laid out to include the lower part of Perdido bay.

6. Plane-table surveys completed at the entrances of the We-thlocco-chee and Homosassa rivers. These complete the topography between Cedar Keys and the mouth of the Chassahowitzka river, Fla.

7. Topography of the shores of Appalachee bay completed between Ocilla river and St. George's sound; and progress made in the plane-table survey of St. James's island, Fla.

8. A hydrographic survey of the Cedar Keys channels, and soundings made on a line from Sea-Horse reef southward to Egmont key, (Tampa bay;) and from Sea-Horse reef westward to Pensacola entrance.

9. The hydrography of Apalachicola harbor, Fla., completed, including the adjacent waters of St. George's sound eastward, to Cat Point, and the hydrography of the eastern part of the sound from Southwest Cape to Crooked river. The hydrography of this part of the sound is now complete to Royal Bluff.

10. A hydrographic survey completed in Maria de Galvez and East bays, and nearly completed in Escambia and Blackwater bays, and connected with the soundings of Pensacola harbor, Fla.

11. Tidal observations made with self-registering gauges at St. Mark's harbor; in St. George's and St. Vincent's sounds, and at Pensacola harbor. These stations form links of a series established for the development of the tidal peculiarities of the Gulf of Mexico.

As an adjunct of the hydrographic work, views have been drawn of the more marked features of the coast for the charts of Cedar Keys, St. George's sound, and Pensacola harbor.

Office-work.—Progress has been made in the drawing of general coast chart No. XIII, Gulf coast, from Waccasassa bay to Choctawhatchee bay, Fla.; on preliminary sea-coast chart No. 25, from Santa Rosa sound to Mobile bay; on coast map and chart No. 81, from Chassahowitzka river to Cedar Keys; on Nos. 84 and 85, from Ocilla river to Cape San Blas; and on No. 88,

from Choctawhatchee bay to Pensacola bay. The drawing of charts of Apalachicola bay and Escambia and Santa Maria de Galvez bays is now in hand. Additions have been made in drawing and engraving to the chart of St. George's sound (eastern part) to that of Pensacola harbor, and to the progress plate. A comparative chart of Pensacola harbor has been drawn, and lines of deep-sea soundings have been added to the general sketch of the Gulf of Mexico.

Telegraphic determination of longitude at Apalachicola, Fla., and Eufaula, Ala.—In order to determine the correct geographical position of one of the points in the triangulation of St. George's sound, an astronomical party was organized in November of last year and placed under the direction of Assistant George W. Dean. The observations to be made included the connection of one of the stations near Apalachicola with the longitude station occupied at Macon, Georgia, in the spring of 1856; the determination of the latitude of Apalachicola, and also the azimuth of a line in the triangulation. Those for latitude and azimuth, and the magnetic observations made by the same party, will be noticed under separate heads.

Sub-Assistant Edward Goodfellow took charge of the astronomical instruments and telegraphic implements, and forwarded them from Baltimore early in December. Mr. Dean, meanwhile, had proceeded to Macon and made preparatory trials to determine the practicability of carrying on the observations by means of a single circuit. The result showed the expediency of an intermediate station, and Eufaula, Ala., was selected as the best connecting one in the telegraphic series. The general superintendent, J. R. Dowell, esq., and Messrs. F. Howe and J. C. Butler, superintendents of the Columbus and Apalachicola, and the Macon and Mobile telegraph companies, respectively, had kindly placed their lines at the disposal of the Coast Survey for the requisite uses after their regular business hours at night.

Temporary observatories having been put up at Eufaula and Apalachicola, Messrs. Dean and Goodfellow observed at the last-named station for personal equation, and then alternately at the two stations through the telegraph line for difference of longitude. One hundred star signals were successfully exchanged by the observers on four nights, and similar exchanges of one hundred and three signals were made during five favorable nights between the stations at Eufaula and Macon. Chronographic comparisons were made on two nights, and the error and rate of each of the clocks used were well determined before and after the comparisons by telegraph.

At Apalachicola three hundred and ten observations were made on sixty-seven stars for local time and instrumental corrections. Sixty-one others were made there on seven, and at Macon seventeen observations on five circumpolar stars, in deducing the value of the thread intervals of Transit No. 6. That for Transit No. 8 was determined at Eufaula by sixty-four observations on eight circumpolar stars. The local time at that station and at Macon, and the instrumental corrections, were ascertained by an aggregate of over six hundred observations, sixty stars being used at Eufaula and sixty-five at Macon.

In his report, Assistant Dean expresses his obligations for facilities extended to his party by the public authorities of the several cities at which stations were occupied in the course of the season.

Latitude observations at Apalachicola, Fla., and at Eufaula, Ala.—These were made by Sub-Assistant Goodfellow, with the zenith telescope, C. S. No. 5, a total of about three hundred and seventy observations being recorded. Thirty-three pairs of stars were observed, exclusive of the circumpolar stars *Polaris* and 51 *Cephei*, on which a hundred and twenty-two observations were made near elongation for the micrometer divisions of the instrument.

Triangulation and azimuth at Apalachicola.—In connecting the longitude station with the triangulation of St. George's sound, Assistant Dean recorded three hundred and twenty-eight angular measurements. These were made with the two feet theodolite, C. S. No. 2, in five positions of the instrument.

The azimuth of the lines of the triangulation was determined by seventy-two observations

on *δ Ursæ Minoris*, near its lower culmination, and seventy on *Polaris*, near its western elongation, in connection with one hundred and twenty observations on an elongation mark.

Magnetic observations at Apalachicola and Eufaula.—The magnetic declination was determined by Assistant Dean, at Apalachicola, by one hundred and eighteen observations, made on three days. For the horizontal intensity and moment of inertia, two sets of observations were made on different days. The magnetic dip was obtained from three complete sets on three days.

At Eufaula similar sets of observations were made to determine the several magnetic elements. At both stations Mr. Dean used the declinometer D 22, (C. S. No. 1,) and the dip circle C. S. No. 4.

Meridian line.—While the observations for longitude were in progress at Eufaula, Ala., Assistant Dean was requested by the city authorities to establish and mark for public use a meridian line in that vicinity. Suitable stone blocks for marking the ends having been provided by the authorities, Mr. Dean promptly complied with their request, and made the requisite astronomical observations with the forty-six inch transit C. S. No. 8. The line ranges through and nearly along the middle of Forsyth street, and is about nineteen hundred and forty-eight feet in length. Its ends are marked by small drill holes in the stone blocks, which were sunk two feet and a half into the ground, the tops being left even with the surface.

Meteorological observations.—The usual meteorological journals were kept during the season at Macon, Eufaula, and Apalachicola, by Messrs. A. W. Thompson and W. D. Storke, the aids attached to the party of Assistant Dean. Readings of the barometer were recorded at all the stations, in connection with readings of the wet and the dry bulb thermometers.

Messrs. Thompson and Storke also recorded the astronomical observations as they were made, and aided in the determinations for longitude.

Assistant Dean returned to the office early in May, and during the remainder of the season was employed in Section I. All the records connected with the observations for longitude, latitude, azimuth, and magnetic and meteorological observations at Macon, Eufaula, and Apalachicola, have been deposited in the office at Washington.

Coast triangulation south of Bayport, Fla.—The triangulation of the western coast of the Florida peninsula south of Cedar keys was resumed on the 25th of November by Sub-Assistant G. H. Bagwell, aided by Mr. M. O. Hering, working with a party in the schooner Joseph Henry. After joining at Raccoon Point (Sketch No. 25) with the stations used last year, Mr. Bagwell extended the triangulation down the coast, passing Bayport, and going southward and westward to the North Anclote keys and Tiger Point. This chain of triangles ranges about thirty-five miles in length from the junction referred to. The instruments used in measuring the angles were the eight-inch No. 36, (Gambey,) and the six-inch Brunner theodolite No. 58.

"The coast included in this triangulation is of the same character as that described in the report of last season. As in previous years, the operations were much retarded by the difficult and dangerous navigation over St. Martin's reef. Below the Anclote keys the coast will be found much more favorable than above, for transportation, and the work can be extended southward from its present limits, into St. Joseph's bay, with greater rapidity than heretofore."

The site for a preliminary and verification base selected last season being yet fifteen miles in advance of the triangulation, its measurement has been deferred, for greater convenience, until the approaching winter. The arrangements, however, have been fully made, and Assistant Gerdes has been instructed to determine the length of the line.

The course and extent of the work done between Bayport and Tiger Point are shown on Sketch No. 25. A synopsis taken from the field-notes is given below:

Stations occupied	12
Signals observed on	32
Angles measured	54
Number of observations	2,550

Field-work was suspended on the 10th of March. The party then returned to New York, and after laying up the vessel, Mr. Bagwell commenced the revision of his records, and went on with the computations connected with the triangulation.

Several years' experience having shown the impracticability of keeping the plane-table work south of Cedar keys up with the triangulation, the party heretofore joined with Sub-Assistant Bagwell worked separately, in order to fill the gap necessarily left while the means required by both parties were supplied with but one vessel. The operations of the plane-table party will be again referred to in the course of this report. As heretofore, such incidental assistance was rendered to it by the party in the Joseph Henry as the steady progress of the triangulation permitted.

A duplicate of the journal of horizontal angles measured below Bayport has been received from Mr. Bagwell.

Triangulation between Ocilla river and St. Mark's, Fla.—A complete connection has been made between the preliminary survey of Ocilla river and that of St. George's sound, and between both and the survey of St. Mark's harbor. This duty was performed by Sub-Assistant S. C. McCorkle between the 7th of December and the close of the following month, the party being then transferred to another locality of the section. In prosecuting the field-work he was aided by Mr. Rufus King, jr., and had in charge the schooner Torrey for transporting camp equipage and instruments. The joinings of the triangulation are shown on Sketch No. 25.

Mr. McCorkle occupied St. Mark's light-house with the six-inch Gambey theodolite, C. S. No. 55, with which all the angular measurements were made, and, by removing the panes of glass temporarily, succeeded in observing on the adjacent stations connected with it in the scheme. An attempt was made to determine the exact position of the Ocklokonee shoal, but without success, the means at the disposal of the land party not admitting of the erection of a suitable signal. It was intended, at the outset of the season, to have a screw-pile signal inserted for the purpose by the hydrographic party, but the calls upon it for general duty postponed that service. In its next return to this section means will be provided for making the requisite determination.

The triangulation on the western part of the coast of Florida is now continuous from Ocilla river, through St. George's sound, to Cape San Blas, a distance, measured along the sides of the angles, of ninety-five miles.

The particulars of the work east of the sound are here given, as compiled from the field-books returned by Mr. McCorkle:

Signals erected	6
Stations occupied	9
Angles measured	35
Number of observations	720

For purposes of verification two of the stations used between St. Mark's and Southwest cape were reoccupied. The triangles of the entire series closed well when tested in the usual way.

Under the head following will be detailed the further service executed by the party in this section of the coast.

Triangulation of St. Vincent's sound, Fla.—This work is an extension to the westward of the triangulation of St. George's sound, the completion of which has been already reported. On the 21st of March Sub-Assistant McCorkle took up work at the line "Oyster Cove —— Middle Bayou," (Sketch No. 25,) and established points at intervals along the coast of the Gulf, towards Cape San Blas. These connect with others on St. Vincent's island, and complete the triangulation of St. Vincent's sound, beyond which, from stations at Indian Pass and St. Vincent's island, the work was continued to the cape, where it was closed for the season on the 20th of April.

Mr. Rufus King aided in the operations of this party.

Sub-Assistant McCorkle thus remarks in reference to the means for continuing the triangulation towards St. Andrew's bay, around the abrupt turn of the coast at Cape San Blas: "I do not anticipate any further trouble in continuing the work over St. Joseph's bay, and towards St. Andrew's, beyond the labor of opening two or three lines."

Some of the lines requiring to be cut through in the triangulation of this season involved severe hardship, particularly on St. Vincent's island, the parts of it necessarily traversed being made up of a succession of ponds and marshes. The latter part of the season, moreover, was very unfavorable, the atmosphere being obscured for a period of six weeks by fires in the woods along the shores of St. Vincent's sound.

The statistics of the work are returned as follows:

Signals erected	9
Stations observed from	8
Angles measured	30
Number of observations	630

The angles were measured with the six-inch Gambey theodolite, C. S. No. 55.

While engaged in this vicinity, Mr. McCorkle made a reconnaissance for a primary base line near Apalachicola, and reports that a practicable site can be had, giving a length of from three and a half to four miles. He states, also, that the line would join readily with the triangulation and astronomical points on St. George's sound, and be convenient of measurement.

At the end of the working season the schooner Torrey, which had been used by the party in this section, returned north, and was laid up at New York.

Triangulation of Santa Maria de Galvez, Blackwater, and East bays, Fla.—As a base for this work, Assistant F. H. Gerdes selected the line which connects Emanuel Point and Garçon Point, (Sketch No. 25,) both of those stations having been occupied in his triangulation of Pensacola bay. From general knowledge of the practicability of the lines required for the survey of Maria de Galvez bay, Mr. Gerdes put up the requisite signals in March, though the haze which then prevailed shut out of view from each other the stations intended to be connected by the observations. In the latter part of that month and the beginning of April, when the atmosphere was so far improved as to render the signals barely visible, two theodolites were employed; the second by Sub-Assistant C. Fendall, under the immediate direction of Assistant Gerdes. The triangles include, as will be seen by the sketch already referred to, the entire shores of Santa Maria de Galvez and its two dependencies, the Blackwater and East bays, and connect those waters with the survey of Pensacola and Escambia bays.

To overcome, in some degree, the unfavorable circumstances under which the observations were made, Mr. Gerdes occupied several of the stations twice, and from others reobserved single angles, and deems it necessary, from the cause just alluded to, that angular measurements should be repeated from two of the principal stations in clear weather. This will be done, if practicable, in the course of the coming winter. The statistics of the triangulation are as follows:

Signals erected	13
Stations occupied	7
Angles measured	43
Number of observations	372

Of the signals erected, eight were elevated tripods, with scaffolds for the theodolite. The instruments used were the twelve-inch Gambey, C. S. No. 16, and the six-inch Gambey theodolite, C. S. No. 75.

In order to complete the preliminary work at the head of Blackwater bay, some few stations will be occupied above Perry's Mill, which is the present northern limit of the triangulation.

Mr. Gerdes had in charge the schooner James Hall, for transportation. His party executed

also the plane-table survey, which advanced as points were furnished by the preliminary work, as will be further noticed under the head of topography.

Other duty performed by the party of Assistant Gerdes in triangulation and topography will be stated in the succeeding chapter.

Triangulation of Perdido bay, Fla. and Ala.—Under the immediate direction of Assistant Gerdes, a reconnaissance for this work was made early in April by Sub-Assistant J. G. Oltmanns. A site was selected near the entrance of the Lower Reach for a preliminary base, the location of which is marked on Sketch No. 25. The line was twice measured with a twenty metre chain, verified in length before and after each measurement, giving for the length of the base 812.45 metres.

Having erected and secured a sufficient number of signals, Mr. Oltmanns proceeded with the angular measurements, using the eight-inch Würdemann theodolite, C. S. No. 87. The triangulation was laid out to include the entrance to Perdido bay and the lower part of the two reaches, extending also across the main body of the bay, below Soldier's creek. The following summary shows the progress made in the work:

Signals set up	10
Stations used	8
Angles determined	23
Number of observations	175

Soundings were made by the land party with the schooner Gerdes through both channels of the entrance into Perdido bay. The result of that reconnaissance, as compared with local information derived by Assistant Gerdes in regard to the depth found the year before, would seem to show an increased capacity of the channels. The change, if not merely temporary in character, may be of considerable importance, and in allusion to it Mr. Gerdes remarks: "The Perdido bar has but little water, and is said to be shifting, or at least has shifted. On account of the abundance of the best kind of timber, which extends back for several miles along the shores of the bay, a favorable improvement in the character of the bar would be of vast consequence. At present a portion of the lumber finds way to market by a branch railroad which connects the Montgomery and Pensacola line with the upper waters of the Perdido."

Under the head of Section VIII mention will be made of other duty performed by Sub-Assistant Oltmanns. He was aided in field-work by Mr. G. U. Mayo.

The preliminary survey at Perdido bay was closed for the season in the latter part of April. Mr. Gerdes then proceeded north, and took up his office-work.

Topography of the We-thlocco-chee and Homosassa river entrances, Fla.—The survey of these entrances, which had been deferred in the progress of the joint work of triangulation and topography south of Cedar keys, for a reason already given, has been completed, and the land-work is now continuous from Cedar keys, southward, as far as Raccoon Point, in the direction to St. Joseph's bay.

Sub-Assistant N. S. Finney, provided with a boat and camp fixtures, took up the plane-table survey about a mile north of the mouth of the We-thlocco-chee in the middle of December. The sheet of that vicinity unites on the north and south with two executed by him in the working season of 1857–'58, the gap in the topography being left, as explained in my last report, to avoid delay in pushing forward the triangulation. This interval includes a stretch, coastwise, of about eight miles, and, besides the mouth of the river last named, takes in the Gulf shore between it and the mouth of Crystal river, as will be seen on the progress Sketch No. 25. On the same sheet Mr. Finney traced the anchorages and boat channels along the shore, as also those leading into the mouths of the rivers.

The work intervening between the portions done last season, including the shores and features of the Florida coast in the neighborhood of Homosassa bay, was resumed on the 10th

of January, and carried to a junction, north and south, with the completed topography. Owing to unfavorable weather, and a long succession of very low tides, the topography was much retarded, but the gap was completely filled in by the 16th of February.

"The character of the coast of Florida in these two gaps is very much like that found above and below, and as described in previous reports. It is a continued belt of marsh, cut by innumerable creeks and bayous, extending, in some places, ten miles towards the interior of the peninsula. Hundreds of small islands are found, partly covered with stunted mangroves, and nearly all overflowed at high water. The channels being left quite dry at low tide has rendered the survey tedious and difficult."

An abstract of the statistics of the season's work is here given as recorded on the plane-table sheets:

Shore-line of coast, reefs, and islands	132 miles.
Low-water line surveyed	56 "
Area, in square miles	19

The triangulation in this quarter is now a full season in advance of the topography, but a suitable boat and fixtures for separate working having been provided, it is hoped that the plane-table party may soon be able to overtake it. For some miles to the southward of Raccoon Point, the present limit of the topographical survey, the nature of the coast presents the same difficulties which mark it between that point and Cedar keys; but nearer to the Anclote keys and St. Joseph's bay the obstacles to progress are not so great.

Some general remarks made by Sub-Assistant Finney in reference to the western coast of Florida, and applying more particularly to the rivers which empty into the Gulf of Mexico, between Cedar keys and Bayport, will be found in Appendix No. 32.

Throughout the entire range of his plane-table work the anchorages in the bays, and near the mouths of the rivers, have been carefully noted on the sheets containing them, and the channels leading up the rivers, to the distance of several miles, have been staked out, and are, in like manner, traced on the maps.

At the close of the season Mr. Finney stored his camp equipments near the mouth of Homosassa river, and returned north to complete his office-work. In referring to friendly acts bearing on the discharge of his duties, mention is made of the names of Hon. A. G. Steele, Capt. J. Tucker, W. P. Thigpen, esq., and Col. E. H. Richards, of Cedar Keys; Major J. Parsons, of Bayport, and A. B. Hahn, esq., of Homosassa. The work in his charge was furthered also by incidental assistance from the party of Sub-Assistant Bagwell, in the schooner Joseph Henry.

Mr. Finney has inked and turned in three sheets of his topographical work of 1858–'59, and the sheet containing the surveys made this season.

Topography of Appalachee bay and of Crooked river, (St. George's sound,) Fla.—The plane-table survey of the coast of Florida, between Ocilla river and St. Mark's harbor, and from St. Mark's entrance, westward, to the mouth of Ocklokonee bay, was taken up by Assistant G. D. Wise in the middle of December, and completed by the end of February. His party in the schooner Howell Cobb was then transferred to St. James's island, and there resumed the survey of the shores of Crooked river, towards the completion of which considerable progress was made before closing work on the last of April.

In reference to the character of the topography on the shores of Appalachee bay (see Sketch No. 25) Assistant Wise observes: "The main land east and west of St. Mark's is very low, and the marshes extend a long distance back. Our anchorage was on the open coast, between two and three miles from the land, in six or seven feet water, and at low tide our small boats would ground when a mile from the shore, which was reached with much difficulty through the mud."

The plane-table work of this party embraces the Gulf shore from Ocilla river, westward, to the completed survey of St. Mark's, and beyond it, in the same direction, the shores of Dickerson's and Oyster bays, to a junction with the topography of St. George's sound. The course of Crooked river, to a distance of about fifteen miles along the western side of St. James's island, was surveyed on a separate sheet, leaving a portion of it yet to be completed on the upper side of the island.

The progress made by the party is shown in the following summary:

Shore-line surveyed	155 miles.
Roads	11 "
Area of topography, (square miles)	70

On the return passage the vessel reached Baltimore on the 11th of May, and was afterwards employed by Mr. Wise in Section III.

The following remark in the report of Assistant Wise refers to peculiarities of the coast of Florida in the vicinity of Ocilla river: "Many of the streams are subterranean, boiling up from great depths in springs of perfect clearness. The Ocilla, Wacissa, Wakulla, and Spring creek, all comprised within the limits of my survey, are of this character. I found bottom in the Wakulla spring at eighty-eight feet, the lead being plainly visible at that depth."

Topography of Santa Maria de Galvez, Blackwater, and East bays, Fla.—It has been already noticed that the preliminary work for the survey of these dependencies of Pensacola bay was executed by Assistant Gerdes, in March last. The topography was based on points provided in the progress of the triangulation, and went on with it jointly. On the west side of Santa Maria de Galvez bay and Blackwater bay, which forms its northern arm and is continuous with its shores, the plane-table survey was extended from White Point (see Sketch No. 26) upwards to Robinson's Point. The south and east shores and land adjacent to the water-line were surveyed from Redfish Point to the head of East bay, and from thence to Catfish Point, which is nearly opposite, to the limit reached on the eastern side of Blackwater bay. At present the topography rests a little below the triangulation, but will advance with it to a point a short distance above the head of that branch of Maria de Galvez bay.

Sub-Assistant Clarence Fendall assisted Mr. Gerdes in the triangulation and plane-table work. A synopsis of the last is thus given in the summary report from the field:

Shore-line surveyed	43 miles.
Area, in square miles	60

The atmosphere was very much obscured by smoke and haze while the party was employed in this section.

For carrying on the work from station to station the schooner James Hall was used.

Assistant Gerdes furnished the shore-line of his survey for the use of the hydrographic party of Lieut. Comg. Phelps.

Hydrographic examination of the Cedar Keys channels, Fla.—Between the 20th of January and the middle of the following month a thorough examination was made of the Sea-Horse Key channel, the Northwest channel, and the North Key passage, into the harbor of Cedar Keys, by the party in the steamer Walker, under Lieut. Comg. J. J. Guthrie, U. S. N., Assistant. The results obtained do not differ materially when compared with the soundings made in the previous examinations, showing, however, less water on the bars.

This survey was made under some disadvantages, in advance of taking up work to which the hydrographic party had been assigned in Section VIII, notice of which will be taken in its place.

The following are the statistics of work in the Cedar Keys channels:

Miles run	467
Angles determined	2,658
Casts of the lead	41,811

In connection with the hydrography, observations were made on the 23d of January and 3d of February for determining the rate of the current off Depot key.

The original records of the work done this year at Cedar Keys were lost by the sinking of the steamer Walker in June last, off Absecom, N. J. Lieut. Comg. Guthrie, on landing at Norfolk after returning from this section, brought to Washington the fair journal of the soundings, and thus it was saved from the disaster which destroyed the results of an arduous season's labor.

Hydrography of St. George's sound, Fla.—A large advance has been made towards the completion of the hydrography of St. George's sound by a party in charge of Lieut. Comg. T. S. Phelps, U. S. N., Assistant Coast Survey, in the steamer Vixen. In the immediate vicinity of Apalachicola, and to the eastward and westward between Cat Point and St. Vincent's Point, (Sketch No. 25,) the hydrography is now complete, and soundings have been made from Crooked river to Southwest cape, supplementary to the survey of the channel which leads into St. George's sound past the eastern end of Dog island. This work, it will be recollected, was in progress last season, when the hydrographic operations were suspended by the death of Lieut. Comg. Duer, while in charge of the steamer Vixen. The space included in the work of this year stretches about fifteen miles along shore, from Southwest cape westward, with an average breadth of about three miles, and embraces Alligator harbor.

In sounding near Apalachicola, Lieut. Comg. Phelps joined his work with the survey of the West Pass made by Lieut. Comg. Duer in 1858, and extended the hydrograpy of the body of the sound eastward to Bulkhead Point and northward to St. Mark's Point, in Eastern bay, a short distance above Apalachicola.

The only part of St. George's sound yet to be covered by the hydrography lies between Cat Point and Royal bluff.

During the month of January the progress of the party was much hindered by adverse weather and by fogs and high winds. The work near Apalachicola was completed at the end of February, and that in the eastern part of the sound within the first three weeks of May, the party being in the interval employed at a third locality of this section.

A summary of the statistics of work in St. George's sound is given below:

Miles run while sounding	761
Angles observed	2,082
Number of casts	60,003
Area sounded out, (square miles)	100

In the following extract from the report of Lieut. Comg. Phelps it is suggested that a change, favorable to the interests of navigation and commerce, may be now going on, tending towards improvement in the depth of water at the East Pass into the sound. He says: "A new channel seems to be opening into the East Pass anchorage to the northward and westward of the present channel. On crossing the bar my attention was called to a dark line of water through the reef, and the boat despatched to sound it found fifteen feet at mean low water. Another season will probably decide whether this channel is to be of value or not. My impression is that a deeper and better channel is opening into the East Pass anchorage."

Three tidal stations were occupied in connection with the hydrographic duties of the party.

While at Apalachicola in January, Lieut. Comg. Phelps, on being applied to by the captain of the bark Gleaner, of Yarmouth, Me., promptly went to the relief of that vessel, the cargo of which had taken fire while she was lying at the East Pass. The steamer Vixen remained

in company all night, but the bark having been scuttled and the fire in her hold thereby extinguished, the steamer returned next day to her working ground.

The officers and crew of the Vixen also rendered effective assistance in stopping the ravages of a fire which broke out in Apalachicola on the morning of the 2d of February. Liberal acknowledgment of this aid has been made by the press of that city.

The United States steamship Roanoke, having touched on several spots in the vicinity of the Warrington navy yard during her stay there in March last, the attention of Lieut. Comg. Phelps was directed to an examination of the character of the bottom in their vicinity, but owing to detention in the mails of certain data sent to him from the office that duty was not accomplished by his party before its departure for the north.

Lieut. Comg. T. A. Craven, U. S. N., formerly Assistant in the Coast Survey, and now in command of the United States ship Mohawk, was incidentally at Pensacola in October and kindly volunteered to make a preliminary examination of the locality. His soundings, made on the 9th of that month, gave a depth of twenty feet and developed a very narrow ridge, which, he suggests, may have been occasioned by a sunken tree, around which the sand is depositing. He thinks also that the docking out from the dry dock may have somewhat increased the deposit.

Hydrography of Escambia, Maria de Galvez, and Blackwater bays, Fla.—The main body of each of these bays, which connect as branches with the waters of Pensacola harbor, was sounded between the 1st of March and the 25th of April, by the party of Lieut. Comg. Phelps, in the steamer Vixen. In the Escambia, the hydrography was carried upwards of ten miles from its junction with the completed work at Pensacola, or from a line crossing five miles southward and westward of Garçon Point. Eastward from the same line the soundings were extended so as to include the whole of the bay of Santa Maria de Galvez, and East bay, and the main body of Blackwater bay. At the close of the season the work had reached Eagle Point, which is a short distance below the entrance of Yellow river.—(Sketch No. 25.)

Two tidal stations were occupied and the observed rise and fall were referred to the bench mark at the Warrenton navy yard.

The statistics of the hydrography returned are:

Miles run in sounding	882
Number of angles observed	2,949
Soundings recorded	66,985

Assistant Gerdes furnished the shore-line for this survey while prosecuting the topography in the vicinity, as before stated. The preliminary chart derived from the joint operations is given as Sketch No. 26, with this report.

The recommendations of Lieut. Comg. Phelps, for buoys near Garçon Point, Redfish Point, and Bartley's Point shoal, as aids for the navigation of Pensacola harbor and its dependencies, were communicated through the department to the Light-house Board in May last.—(Appendix No. 45.)

The steamer Vixen, after receiving some slight repairs at New York, in July, was employed until the close of the season in Section I.

Soundings in the Gulf of Mexico.—In passing to Cedar Keys, on the 15th of January, Lieut. Comg. Guthrie, U. S. N., in the steamer Walker, started a line off Egmont key, (Tampa,) and carried soundings along the meridian northward to Sea-Horse Key light at Cedar Keys. The greatest depth (ten fathoms) was found when the vessel was passing abreast of St. Joseph's bay. Throughout the entire distance the bottom brought up was coarse grey sand.

On leaving Cedar Keys, in the middle of February, the same party took soundings on a line due west from the lower end of Sea-Horse Key shoal (Sketch No. 27) to the meridian of Pensacola, and from thence north to the entrance of that harbor. Out from Cedar Keys the slope

of the bottom of the Gulf of Mexico was found to be very gradual, giving a depth of only twenty-five fathoms when on the meridian of Apalachicola, and parallel of Sea-Horse key, but a little to the westward of the meridan of Cape San Blas the depth is forty-seven fathoms, and at a position nearly south of St. Andrew's bay the water deepens to one hundred fathoms. About thirty miles east of the meridian of Pensacola the depth found was two hundred and ten fathoms, and at the western end of the course run by the steamer four hundred and twenty, showing a very steep declivity in that part of the Gulf, the depth actually doubling in a western range of about twenty-five miles.

The results obtained confirm, in a general way, the depths found in previous seasons by Commander B. F. Sands, U. S. N., when in charge of the hydrographic party, in the steamer Walker.

On the course running north towards Pensacola, and when about sixty nautical miles from it, Lieut. Comg. Guthrie found a depth of five hundred fathoms. From that position the soundings decrease very rapidly in approaching Pensacola.

On going out from Apalachicola, with the steamer Vixen, Lieut. Comg. Phelps carried a line of soundings from the South shoal, off Cape San Blas, to the outer buoy at Pensacola entrance, and on his return from extended hydrographic duty in that vicinity, which has been separately described, made soundings from the same buoy along a line to the West pass of St. George's sound.

In crossing this section on his return to Key West, from special duty at Mobile, in the steamer Corwin, Lieut. Comg. Wilkinson observed with the deep-sea thermometer and recorded the temperature found in the Gulf water to a depth of two hundred fathoms. Besides the record of the air thermometer and the register at the depth just stated, the temperature was noted in twenty-three positions at the surface also, and at ten, thirty, and one hundred fathoms. In latitude 24° 05½′ N., longitude 82° 52′ W., (see Sketch No. 27,) the temperature found at one hundred and ninety fathoms was thirty-eight degrees by the Saxton thermometer, that of the surface being at the same time eighty-three.

In the Gulf sounding an aggregate of one hundred and fifty-eight casts were made.

Tidal observations.—In conformity with the plan of operations sketched out in my report of last season, several self-registering tide gauges have been employed in this section, under the care of Mr. A. C. Mitchell. With the aid of qualified observers a regular series of observations have been kept up at St. Mark's, at Dog island, at New inlet, and at St. Vincent's island. At most of these stations complete series of results were obtained and the gauges have been transferred to others in the vicinity of the Mississippi delta.

I am indebted to S. Thayer Abert, esq., civil engineer at the United States navy yard, at Pensacola, for the records of a self-registering gauge, the charge of which was kindly undertaken by him when it was set up at that station. Through his interest in the subject the records received at the office in Washington, have been found highly satisfactory.

It is expected that the observations made in this section will, when discussed in conjunction with those taken along the Florida reef, and others near the delta of the Mississippi, furnish means for investigating the anomalies noticed in the tides of this part of the Gulf coast.

SECTION VIII.

FROM MOBILE BAY TO VERMILION BAY, INCLUDING THE COAST OF MISSISSIPPI AND PART OF THE COAST OF LOUISIANA.—(SKETCH H, No. 28.)

The usual number of parties has been at work in this section, but the loss of the records of the hydrography in the wreck of the steamer Walker, by collision at sea on her return to the north, has caused much of the hydrographic labor to be in vain. Unless that steamer is replaced, the hydrography must lag and my estimates of progress be entirely set at naught. This would be a result much to be deplored, as the work of the section is so important and has made such fair progress towards completion.

The special surveys made in Mobile harbor for the commissioners on its improvement, and at their expense, has received their grateful acknowledgments.

The order of the detailed notices of work is as follows :

1. The connection of the survey of Mississippi sound with that of the delta, by triangulation from Point Fortuna, across Isle au Breton sound, to the preliminary base at the head of the passes of the Mississippi river.

2. The completion of the triangulation and topography of Côte Blanche bay, and determination of the magnetic elements at Côte Blanche island. The topography includes a part of Marsh island.

3. An extension westward of the plane-table survey of Lake Pontchartrain to Ragged Point and Bayou Le Bar. This work completes the topography of the eastern half of the lake.

4. Completion of the topography of the North, Northeast, and Southeast Passes, and Passe à Loutre, with intermediate details of the Mississippi delta, and determination of the magnetic elements.

5. A hydrographic re-survey of Mobile harbor, including the adjacent parts of the Mobile, Spanish, and Tensaw rivers, and general reconnaissance of the channel of the entire bay to the Lower Fleet. This work was executed for the commissioners authorized by the State of Alabama to decide in regard to plans for improving the water approaches of Mobile harbor. In connection with it a physical examination was made, including observations of the tides and currents at various points in the bay between its head and the waters of the Gulf of Mexico.

6. Hydrographic surveys of Passe à Loutre, the Northeast, North, and Southeast Passes of the Mississippi river. The records of soundings and other material resulting from this work were lost by the sinking of the steamer Walker. By the same disaster all the notes and journals connected with a hydrographic survey of Chandeleur sound were also lost.

7. Tidal observations at the Mississippi passes, and at Isle Dernieré, for comparison with others made at stations on the eastern coast of the Gulf of Mexico.

In the vicinity of Chandeleur island light, and of the Mississippi delta, views have been drawn for charts of the Gulf coast.

Office-work.—The drawing and engraving of coast map and chart No. 91, from Bon Secours bay to Round island, and of the map of the Rigolets have been completed, and additions made to the progress sketch. Progress has been made in the drawing and engraving of coast map and chart No. 92, from Round island to Grand island, La., and in the drawing of general coast chart No. XIV, from Pensacola bay to the Mississippi delta, and coast map and chart No. 93, from Lake Borgne to Lake Pontchartrain.

Triangulation of the western side of Isle au Breton sound, La.—Resuming work on the 27th of November, at Point Fortuna, (Sketch No. 28,) Sub-Assistant Stephen Harris, with a party in the schooner Twilight, extended the triangulation connected with Mississippi sound, southward and westward over the islands and west shore of Isle au Breton bay, and over both shores of Oyster bay, and part of Bay Rondo, and joined at the head of the passes on the Mississippi river with the preliminary base measured by Assistant Gerdes in 1857. In the course of the work a number of tertiary points were determined for plane-table use in the immediate vicinity of the Mississippi, and on the shores of Isle au Breton sound. The triangulation was closed on the 12th of May, the vessel being laid up during the summer at Pascagoula.

A summary from the report of Mr. Harris gives the following particulars relative to the field-work:

Stations occupied	19
Signals observed on	33
Number of observations	3,720
Area of triangulation, (square miles)	284

On visiting the stations used in other parts of the same range of triangles, and those in

Chandeleur sound, Sub-Assistant Harris found all the marks in good condition, excepting those at the station "Old Harbor key;" and in reference to them he says: "The island on which this station is situated appears to have been swept by the sea in the course of last summer, and all traces of the station are destroyed."

Sub-Assistant R. E. Halter was attached to the triangulation party, and assisted Mr. Harris in his reconnaissance for stations, and also in making the angular measurements. The instruments used were the ten-inch theodolite, C. S. No. 79, and the six-inch, C. S. No. 84.

The triangulation of the eastern coast of Louisiana is now continuous and complete along Mississippi sound and the main land to the western side of the delta, and embraces also the several passes of the Mississippi. It yet remains to connect the Chandeleur islands with the general work near the delta, and for that duty directions are now about to be issued.

Mr. Charles S. Peirce served as aid in the party of Sub-Assistant Harris until the end of the working season at the south, and then resigned.

Sub-Assistant Harris has duplicated and deposited in the office with the originals his records of the horizontal angles measured in Isle au Breton sound, and full descriptions of the marks placed at the stations.

Triangulation of Côte Blanche bay, La.—This work was resumed early in February, and has been completed by Sub-Assistant Oltmanns, with a party operating as heretofore under the general direction of Assistant Gerdes. The triangulation was taken up on the line joining Côte Blanche island and Musquito station, (Sketch No. 28,) and from thence carried westward quite to the entrance of Vermilion bay. Owing to the high stage of water this season the schooner Gerdes, which was used in the triangulation and plane-table work, was taken without difficulty to the vicinity of the station at Côte Blanche island.

All the station-marks westward of Atchafalaya are reported by Mr. Oltmanns as well secured by screw-piles or other sufficient means, and those used in past seasons can so far be readily identified.

Ten points were determined in position within the range of the work of this season. The following additional particulars of the triangulation are given in the usual form:

Signals erected	11
Stations occupied	7
Angles measured	23
Number of observations	330
Area of triangulation, (square miles)	70

Mr. G. U. Mayo aided in the triangulation work of Côte Blanche bay. Sub-Assistant Oltmanns was subsequently employed in Section VII, as already stated.

Topography of Lake Pontchartrain, La.—On the north shore of Lake Pontchartrain the plane-table survey has been extended by Sub-Assistant Malcolm Seaton from Bayou Bonfouca westward to a station two miles beyond Ragged Point. The details include the shell ridge, which lies a little above high water-mark, and the fringe of marsh, varying from a quarter to a mile and a quarter in width, between the lake margin and a belt of pine woods which follows the shore. The shell ridge is covered with brush and scattered live oak trees. Bayou Lacombe, the only stream of note represented on the sheet, has a good depth of water; but the bar at its mouth will admit only vessels drawing less than four feet.

On the south shore of the lake the topography was pushed from Bayou Coushon (Sketch No. 28) westward to Bayou Le Bar, or two miles and a half to the westward of the Jefferson rail-road wharf; and from the water-line southward to the Gentilly Ridge, which follows the southern shore at a distance of from two to two and a half miles. The dense cypress swamp, broken by small passages, which lies between the ridge and the lake, constitutes the main topographical feature of the second sheet. Within its limits are also included the Pontchar-

train railroad, Bayou St. John, the New canal, Jefferson railroad, Indian bayou, and Bayou Tchoupitoulas, with the settlements on Gentilly and Metairie ridges.

The details comprised on the two sheets are as follows:

Shore-line of lake	27	miles.
Interior marsh-line	38¼	"
Bayous and canals	38¾	"
Highway and railroads	27¾	"
Wharves	2¾	"
Area of topography, (square miles)	45	

Sub-Assistant Seaton was aided in the field by Mr. W. W. Harding. The plane table work was commenced on the 25th of January. For the service and transportation connected with it, the party used the schooner G. M. Bache.

This survey joins with the western limit of work executed last year by Sub-Assistant W. S. Gilbert.

A short period at the outset of the present surveying season was employed by Mr. Seaton at the eastern entrance of the Rigolets, in duty, which will be referred to again in this chapter.

At intervals, in the course of the summer, while employed in topography on the coast of Texas, Sub-Assistant Gilbert inked the sheet containing his field-work of the previous year on the shores of Lake Pontchartrain, and forwarded it to the office. Mr. Seaton's plane-table sheet of the north shore of the lake has also been received.

Topography of Passe à Loutre, (Mississippi delta,) La.—The large sheet worked on last season by Assistant F. H. Gerdes, and intended to embrace the eastern part of the delta to the head of the passes, was taken up in the latter part of December, and completed in the following February. Its limits (Sketch No. 28) now include the banks of the Mississippi river, from the north end of the preliminary base to the head of the passes; the banks of Passe à Loutre and North Pass, surveyed this season; and additional details completing the topography of the Southeast Pass; the shores of Bay Rondo; Robinson's and Parry O'Niel's reefs; and the numerous bays, bayous, and ponds to the north of Passe à Loutre, with the mud flats and islands (some eighty in number) of Blind bay and Donkey bay, which break the land between it and the Southeast Pass. "The greatest difficulties in the topographical survey were encountered in these two bays, on the shores of which the reeds were so high as to make it impossible to work with the plane-table. To overcome these, high stakes, marked by flags of different colors, were set up along the water-line, and determined in position from the adjacent light-houses and tripods used in the triangulation."

The station-points marked in the preliminary survey of the eastern part of the delta are reported by Assistant Gerdes as being yet in good order.

Sub-Assistant Clarence Fendall assisted in the season's work, and inked the topographical sheet, to which was added, by the labors of the party, an aggregate of a hundred and forty-two miles of shore-line. The area of the whole, embracing the work partially traced in last season, is about a hundred square miles.

The schooner James Hall was in service in prosecuting the survey of the delta.

Assistant Gerdes has sent to the office the completed topographical sheet of Passe à Loutre and vicinity, (Sketch No. 31.)

Magnetic observations at the Mississippi delta.—Near the triangulation stations marked "Cubit" and "Southeast Pass" on the progress sketch, (No. 28,) and at a third in the vicinity of the Passe à Loutre bar, Sub-Assistant J. G. Oltmanns, under the direction of Assistant Gerdes, determined the dip and magnetic intensity, making two sets of observations for each of the elements, and four, in addition, for the intensity, by noting the deflections of the needle. At the first-named station the declination was also ascertained by observations made every five minutes within a period of two hours, and at Passe à Loutre at intervals of five minutes during

three hours. These observations were made on separate days in December and January. Mr. Oltmanns used the declinometer No. 2, and dip circle No. 8. The collimator No. 6 was used in determining the declination, and also for noting vibrations and deflections; collimator No. 17 being kept suspended during the time employed in observing the deflections.

The observations at "Cubit" were made on the 15th, and those at Southeast Pass on the 21st of December. The series at Passe à Loutre were taken on the 3d of January. Mr. Oltmanns has furnished for the archives the notes and records made in the several determinations and the field computations of the work.

Topography of Côte Blanche bay, La.—Following his own triangulation of this season, Sub-Assistant Oltmanns pushed the plane-table work westward from last year's limit at Côte Blanche island (see Sketch No. 28) to the entrance of Vermilion bay, and also along the north shore of Marsh island, from the entrance of that bay, eastward, to Musquito station, completing the survey of the entire shores of Côte Blanche bay.

Mr. Oltmanns was aided in this work by Mr. G. U. Mayo, and had the schooner Gerdes in charge, as heretofore, for the transfer of camp fixtures and instruments.

All the shores represented on the topographical sheets were found very soft and marshy, except for a short distance on the main or north side of Côte Blanche bay, where the soil was firm and solid.

As already stated, the vessel used, drawing usually six feet, was taken without difficulty quite through the bay to the station on Côte Blanche island.

The shore-line run by Sub-Assistant Oltmanns while prosecuting the triangulation was forty miles. This joint work extended over an area of about seventy square miles, occupying his party during February and March. At the close of that period the schooner Gerdes was transferred for service in Section VII.

The plane-table sheet of Côte Blanche bay (west) has been inked and filed at the office.

Magnetic observations at Côte Blanche island, La.—At a station fifty metres north of the triangulation point on Côte Blanche island (Sketch No. 28) Sub-Assistant Oltmanns determined the magnetic declination on the 3d of March, by observing, at intervals of five minutes, during six hours. The dip was ascertained by observing four sets of observations, and the horizontal intensity determined from two sets of vibrations in connection with four sets of deflections. The instruments used were the declinometer No. 2, and dip circle No. 8.

These observations were made while the triangulation and plane-table survey of Côte Blanche bay were in progress. The records and notes connected with them have been filed at the office as usual.

Hydrographic examination of Mobile bay and harbor, Ala.—In pursuance of an arrangement with commissioners acting under authority of the State of Alabama, and by authority of the Treasury Department, a special hydrographic survey has been made of the lower part of Mobile river and of Spanish river, below its junction with the Mobile; as also of the lower part of the Tensaw, and the entire waters of the harbor in the vicinity of the city of Mobile. The soundings from the head of the harbor were carried to deep water, south of Dog river bar, and from thence a general hydrographic reconnaissance was made through Mobile bay to the Lower Fleet.

This resurvey was made by Lieut. Comg. John Wilkinson, U. S. N., Assistant Coast Survey, with a party in the steamer Corwin, between the 4th of May and the 16th of June. His party had been previously employed on the Florida reef. The object of the work was fully set forth in correspondence which passed through the department in March last. Lieut. Comg. Wilkinson conferred personally with the engineer of the commissioners, Captain Leadbetter, and such slight deviations as were deemed advisable were made, in prosecuting the soundings, under the general instructions given to the chief of the hydrographic party. The following are the statistics of the work:

Signals established	60
Miles run in sounding	395
Angles determined	3,833
Number of soundings	37,535
Area sounded out, (square miles)	8½

In connection with the hydrography, tidal observations were made by the party at St. Francis street wharf, in Mobile, at the mouth of Chickasaw bayou, and at Great Point Clear.

The character of the bottom of the harbor was ascertained by numerous borings to the depth of sixteen feet from the surface of the water. Specimens were taken in the same way from the beds of the several rivers before named, and from Dog river bar and along the line of deep water to the Lower Fleet. Particular pains were taken in the investigation of the character of the bottom through Choctaw Pass and that of Dog river bar, samples of the materials brought up in each case being preserved and labelled.

The land positions necessary for the hydrographic operations were furnished by Assistant Henry Mitchell, who was charged also with special observations requisite in regard to the tides and currents, which will be more particularly enlarged upon hereafter.

The steamer Corwin returned to New York early in July, and until the close of September was employed in connection with hydrographic service in Section I.

Soundings in the Rigolets, La.—Before taking the field for plane-table duty in January, Sub-Assistant Seaton, with his party in the schooner G. M. Bache, made supplementary soundings at the eastern entrance of the Rigolets, and forwarded to the office the sheet containing them. This, when taken in connection with a sheet executed last year by Sub-Assistant W. S. Gilbert, furnishes material for a map of the entire passage between Lake Borgne and Lake Pontchartrain, including the approaches of both entrances. The work was concluded on the 19th of January. About nine hundred casts of the lead were made by the party of Mr. Seaton.

Hydrography of Chandeleur sound, La.—Inside of the Chandeleur islands, and in the upper part of the sound, Lieut. Comg. J. J. Guthrie, U. S. N., Assistant in the Coast Survey, joined with the hydrography of a previous year as left by Commander B. F. Sands, and continued the work from the vicinity of the Chandeleur light-house, southward, to Pelican key. The hydrography was carried about ten miles to the westward from the line of the islands. This work was executed in May, after the completion of a survey, which will be referred to under the next head.

The following statistics are taken from an abstract left at the office by Lieut. Comg. Guthrie just previous to the loss of the steamer Walker off the coast of New Jersey in June last, by which disaster the journals and details of the work were unfortunately lost:

Miles run in sounding	244
Angles determined	1,116
Number of positions	187
Number of soundings	13,072

Hydrography of the Mississippi Passes, La.—The survey of the several passes at the eastern side of the Delta was completed in the beginning of May by the hydrographic party in the steamer Walker, in charge of Lieut. Comg. Guthrie. It follows the land-work executed by Assistant Gerdes, of which notice has been taken in its place in another part of this chapter. The soundings included the approaches and the channels of the north, the northeast, and the southeast pass, and Passe à Loutre, in each of which the hydrography was carried upward to the main body of the Mississippi. This work was commenced on the 22d of March, after the completion of duty by the party in Section VII, (Sketch No. 31.)

I have elsewhere referred to the loss of the steamer Walker and the original records by a collision off Absecom, N. J., while on her passage from Norfolk to New York. A synopsis

taken previously from the hydrographic journal, and brought to the office by Lieut. Comg. Guthrie soon after his arrival at Norfolk, gives the following statistics of soundings made at the delta of the Mississippi.

Miles run	612
Angles measured	3,657
Number of casts of the lead	34,916

The hydrography of the passes was commenced on the 22d of March.

Physical survey of Mobile bay.—In close connection with the special hydrographic survey of the upper part of Mobile bay, a limited physical examination of the whole was made under my direction in May last by Assistant Henry Mitchell. This work was done at the expense of the Mobile harbor commission, and comprises observations of the tides and currents taken at certain points, as characteristic of the entire bay for a limited period of the year when considered with reference to the natural causes which, at that season, tend to alter its condition in particular localities. Notes were at the same time made of the effects of the winds and waves upon the channels and shoals. The observations were designed to facilitate the proposed improvement of the water approaches to the city of Mobile, and the results show, in a striking manner, the importance of obtaining data by a systematic survey in advance of such undertakings. As an instance, the following remark, taken from the report of Mr. Mitchell, is in point: "The current observations which were made at several different depths reveal the nature and power of the scouring forces that maintain the channels. These forces are found to follow, in the lower water strata, certain laws often quite at variance with those of superficial movements, showing that conclusions hastily drawn from passing observations upon the surface currents may be entirely fallacious."

The cause of the formation of the hard crust of sand at Choctaw bar was clearly traced, as also the nature of the currents of Choctaw Pass, and of those prevailing between Spanish river entrance and the bar.

Assistant Mitchell remarked that the regularly recurring sea-breezes of the summer from the Gulf of Mexico instead of checking the force of the ebbing waters of the rivers, and compelling a deposit of their sediment, simply restrain the surface current.

"The observations were extended several miles beyond the outer bar, and the existence of a coastwise current, or at least a strong easterly movement, was determined." Fourteen current stations were occupied, and at each of them uninterrupted observations were made at short intervals for an entire tidal day. In most cases the motion of the water was noted at three different depths.

While the current observations were going on, the rise and fall of the tide was recorded every half hour at St. Francis street wharf, in Mobile, and during a period of six weeks in all from the commencement of operations. In order to develop the character of the tide-wave in its progress up the bay, simultaneous observations were made for short periods at Fort Morgan, at Great Point Clear, and at Magazine wharf, near Chickasaw Bogue.

Assistant Mitchell was aided in this work by Messrs. W. T. Bright and L. M. Johnson. The schooner Gerdes was used in transporting the party from station to station.

The records in duplicate of observations on the tides and currents have been filed in the office.

Tidal observations.—Self-registering tide-gauges were erected in the summer at the Southwest Pass of the Mississippi, and at Isle Dernière, and are intended to remain long enough to complete series of observations like those mentioned under the head of Section VII, as having been taken from St. Mark's to Pensacola at several stations along the coast of the Gulf of Mexico. These are now working in charge of Mr. A. C. Mitchell.

Day observations have also been made at Passe à Loutre.

The observations at the delta are designed to be used in comparison with those made in the eastern side of the Gulf for developing, if practicable, the general features of the law which governs the tides of the Gulf, or at least for classifying their anomalies.

The observers employed in this and in the preceding section are Messrs. P. H. Donegan, G. W. Maslin, C. Keyser, D. M. Hodges, W. Logan, and G. A. Floyd.

SECTION IX.

FROM VERMILION BAY TO THE RIO GRANDE BOUNDARY, INCLUDING PART OF THE COAST OF LOUISIANA AND THE COAST OF TEXAS.—(SKETCH I, No. 32.)

The triangulation in this section has made a great leap forward, covering Corpus Christi and Nueces bays. A second triangulation party has been detailed to work eastward from Galveston during the coming season. The topography keeps within a season of the triangulation. The hydrography outside has lagged, and a great effort is required to bring it up to time, which will be made, if practicable, in the course of next year.

The operations of the three parties comprise the following work:

1. The triangulation of Corpus Christi and Nueces bays, and an extension coastwise of the triangulation from Aransas Pass southward to Laguna del Madre.

2. A plane-table survey of the coast of Texas, including St. Joseph's island and the adjacent parts of Matagorda and Mustang islands. This work completes the topography of San Antonio bay, and embraces the shores of Musquit and St. Charles' bays, with parts of the shores and the shell reefs and islands of Aransas bay.

3. The extension of soundings inside of Matagorda bay, from the entrance northward and eastward to Palacios Point, and northward to the entrances of Trespalacios, Caranckaway, and Lavaca bays.

Office-work.—Progress has been made in drawing and engraving coast map and chart No. 108, Matagorda and Lavaca bays. The drawing of general coast chart No. XVI, Gulf coast, from Galveston bay to the Rio Grande, and that of coast map and chart No. 109, from Matagorda bay to Aransas bay, has been continued, and additions have been made to the progress sketch.

Triangulation of Corpus Christi bay, Texas.—This work connects with the triangulation of the coast of Texas, which has been pushed southward and westward from Matagorda by Assistant S. A. Gilbert. His party took the field in January and resumed operations at Aransas light-house. From the line joining that station (Sketch No. 32) with station "Shell Bank," in the lower part of Aransas bay, the triangulation was continued southward to the head of Laguna Madre, and westward so as to include the entire shores of Corpus Christi bay. In the same direction signals were erected along the shores of Nueces bay, and several of the stations necessary for embracing it in the triangulation were occupied with the theodolite. The chain of smaller triangles is laid out to extend to the head of the bay. Measured along the sides of the triangles which rest on Mustang island and Padre island, the advance made in the work coastwise is rather more than twenty-five miles.

The early part of the season on this reach of the coast of Texas was marked by prevailing fogs, brought by easterly and southerly winds, and, contrary to his past experience on the Gulf coast, Mr. Gilbert found that these were not dispersed by the northers, but that the atmosphere was left by them hazy and tremulous to an unusual degree. The unfavorable period was employed by the party in visiting and securing stations already occupied, and in erecting signals for carrying the triangulation forward.

Before leaving the section, a general reconnaissance was made in the upper part of the Laguna Madre to determine the best means for continuing the work below Corpus Christi.

The following particulars refer to the progress made this season:

Stations occupied	12
Signals observed on	32
Angles measured	80
Number of observations	2,120
Area of triangulation, (square miles)	414

The field-work was continued until May.

Assistant Gilbert was aided in the work by Mr. Charles Hosmer. The angles were measured with the Gambey theodolites, ten-inch, No. 82, and six-inch, No. 12.

Mr. Gilbert's remarks on the character of the shores of Corpus Christi bay, in continuation of his general description, given in my last annual report of the coast between it and Matagorda entrance, will be found in the Appendix, (No. 34.)

The records and field computations connected with the triangulation work of the present year have been received at the office.

Topography of San Antonio, Musquit, and Aransas bays, Texas.—The survey taken up by Sub-Assistant W. S. Gilbert, at Webb's Point, (Sketch No. 32,) and carried southward along the western shore, completes the topography of San Antonio bay. In connection with this, the lower part of Matagorda island was surveyed, and the plane-table work pushed southward and westward quite through the broken passages and reefs lying between San Antonio and Aransas bays.

For the purpose of keeping pace on the outer coast while he was at work on the main land, Mr. Gilbert divided his force, and the survey of St. Joseph's island was assigned to Mr. T. C. Bowie, the aid of the party. That duty was prosecuted steadily and completed, Mr. Gilbert meanwhile proceeding westward with a separate plane-table in the survey of the shores of St. Charles' bay. The detailed work in that direction was carried several miles westward of Lamar, and the preliminary work continued to embrace part of the shore-line of Copano bay. Live Oak Point was surveyed, as also Lap reef and all the shell banks and reefs of Aransas bay.

The two divisions of the party were again joined at a station near the lower end of St. Joseph's island, and the topography of the outer coast was extended southward and westward across Aransas Pass, including, in its course, two miles of the upper part of Mustang island. From the light-house at Aransas Pass, the southern shore of Aransas bay was traced to the Shell Banks, the position of which is marked on the progress sketch.

The party took the field on the 5th of January. Mr. Bowie remained in the section until the 1st of April, and then, at the direction of Sub-Assistant Gilbert, returned to the office and inked his completed plane-table sheet. With a small number of hands, Mr. Gilbert continued the topographical survey until the 14th of July. An extent of about twenty-seven miles of Gulf coast is represented on the sheets. The aggregate statistics of details are thus stated in the report from the field:

Shore-line surveyed	278 miles.
Area, (square miles)	127

The remarks given in the Appendix (No. 33) result from the personal observations made by Sub-Assistant Gilbert, while he was prosecuting the topography of the shores of San Antonio and Aransas bays.

The plane-table sheet, inked by Mr. Bowie, containing the survey of the lower part of San Antonio bay, has been registered in the office.

Hydrography of Matagorda bay, Texas.—The soundings made this season by the party of Lieut. Comg. W. Ronckendorff, U. S. N., Assistant Coast Survey, in the schooner Arago, complete the hydrography of the main body of Matagorda bay. The work was taken up at the end of June and joined at Palacios Point (Sketch No. 32) with the soundings made last year

by the party of Lieut. Comg. Duer, and from that limit extended towards the entrance. It there connects with the survey of the approaches made in 1857 by Lieut. Comg. Febiger, and, stretching northward, was carried to the entrances of Lavaca, Caranckaway, and Tres-palacios bays. These, as well as part of the northern reach of Matagorda bay, above the town of Matagorda, yet remain to be sounded out. The following summary shows the progress made by the party:

Angles determined	2,501
Positions used	1,268
Miles run in sounding	529
Number of casts of the lead	32,086

In connection with the hydrography, the tides were observed at Pass Cavallo and at Indianola.

The schooner Arago, on the return of the party from this section, reached New York on the 24th of August.

SECTION X.

FROM SAN DIEGO, OR THE SOUTHERN BOUNDARY ON THE PACIFIC, TO THE FORTY-SECOND PARALLEL, INCLUDING THE COAST OF CALIFORNIA.—(SKETCH J, Nos. 33 and 34)

The usual parties, under the same chiefs, have been occupied in this section in the following work:

1. The completion to Santa Barbara of the main triangulation on the shore of Santa Barbara channel, and the triangulation of Santa Rosa and San Clemente islands.

2. Astronomical observations at Ross Mountain, Cal., in connection with the work of main and secondary triangulation. These operations complete the preliminary work between San Francisco bay and the mouth of Russian river.

3. The completion of plane-table work on the shores of Drake's bay, Cal., and topography of Petaluma creek, for the chart of San Pablo bay.

4. Hydrography at the mouth of Salinas river. A re-survey of the Oakland bar and examinations at the mouth of Sacramento river. The coast hydrography has been extended northward from Duxbury reef, and now includes Drake's bay and Lagoon and Tomales bay. Petaluma creek has been sounded out.

5. Tidal observations.

The beautiful charts of San Francisco and San Pablo bays are the results, in part, of the seasons's labor in the office.

Office-work.—Preliminary charts of San Pedro harbor and Crescent City harbor have been drawn and engraved, and the engraving of the charts of San Francisco bay and Humboldt bay; that of the topography of San Pablo bay, and of the additions to Alden's reconnaissance has been completed. Additions have been made to the progress sketches, and the drawing of a coast map and chart to include San Francisco bay and harbor has been continued.

Triangulation of the Santa Barbara channel and islands, Cal.—At the most favorable period of the winter of 1859–'60, Assistant W. E. Greenwell occupied Saddle mountain, situated about eleven miles northeast of Point Duma, as a station in the main triangulation which passes northward and westward (Sketch No. 33) along the shore of the Santa Barbara channel. Before commencing his observations the four primary stations connected with Saddle mountain were visited, and the requisite signals were set up. The angles were measured with the eight-inch Gambey theodolite, C. S. No. 44. This duty actively engaged the party between December 17 and the 21st of the following February. Mr. Greenwell then returned to San Francisco, the frequent interruptions by rain and protraction of labor by the difficulty of access to the station on Saddle Mountain, having well advanced towards a close the only part of the season which permits observations to be made on the longer lines of the triangulation of this part of

the coast of California. On the 1st of May he transferred his party in the schooner Humboldt to Santa Rosa island. Near its northern extremity a base line was measured with wooden bars cut to the length of eight metres and supported by trestles. The distance between the ends of the line, as determined in this way, was 1277.26 metres. Having completed the preliminaries, Assistant Greenwell at once laid out and measured a chain of triangles which includes the entire shore of the island, (Sketch No. 33,) excepting a few miles along its southern side. The points now determined are quite sufficient for the plane-table survey. Mr. Greenwell then took up the triangulation of San Clemente island. Near the north end of it a site suitable for a short preliminary base was found and a length of 807.92 metres, measured by the means just referred to. In connection with the line a triangulation was carried southward to a point about midway between the two extremities of the island. The work was continued on San Clemente until the end of August, and its further progress for the season being then stopped by a settled fog, the party sailed for Santa Barbara.

The following are statistics of the triangulation on the main and islands:

Signals erected	41
Stations occupied	22
Number of observations	4,008
Area of triangles, (square miles)	542

The character of the two islands over which the work was extended has been given in my previous annual reports. Both are destitute of timber, a condition which made the labor of carrying signals to all the stations observed on a matter of great difficulty. Each of the islands, moreover, has only three anchorages. Those at Santa Rosa are near its eastern side and not far apart. Two of the anchorages of San Clemente are very near to its northern extremity, and the third is at its extreme southern end.

Assistant Greenwell states that during last fall eight thousand head of cattle were transported from Santa Rosa island to the main, leaving still some five thousand head on it. He estimates that the pasturage would sustain from fifty to eighty thousand. It is particularly well adapted to the raising of sheep. Water is abundant at all seasons on Santa Rosa, and is also found in summer on the southeast end of San Clemente, being there the product of the copious rains of the preceding winter collected in large basins.

All the primary stations were visited by Mr. Greenwell and secured against disturbance from natural causes. He has turned in all the records and note-books connected with the triangulation in the vicinity of the San Pedro base and with that on the islands Santa Cruz, San Nicolas, and San Miguel.

Astronomical observations.—On the night of the 26th of March, Assistant George Davidson successfully observed seven occultations of the Pleiades by the dark limb of the moon, at the primary station, Ross mountain, near Russian river, Cal. Full preparation was made for observing the occultations of the same group on the 13th of July, but without success, on account of the low altitude of the moon.

Before leaving Ross mountain, Mr. Davidson, in conjunction with his aid, Mr. Fauntleroy, also observed reciprocal zenith distances between that station and Bodega Head, (see Sketch No. 34,) for the purpose of determining the co-efficient of refraction for that part of the coast of California. These observations were made at every hour of the day selected for them, and from 7 o'clock in the morning until 5 o'clock in the afternoon, with the vertical circles Nos. 28 and 80, the latter being spared for use by Sub-Assistant J. S. Lawson. Two barometers were kindly loaned by Lieut. R. S. Williamson, of the Topographical Engineers.

The height of the station, "Bodega Head," was determined by levelling to connect with the observations, the levels being referred to the station-mark on the Head and also to the bench-mark of the hydrographic party at the beach as well as to another established by

Assistant Davidson. "The bluff above this bench-mark is about eighty feet high, nearly perpendicular, very much broken, and covered with chapparal, but in levelling, long back, and fore sights were used along the face of the bluff."

In the course of the season the height of Ross Mountain station will also be ascertained by a line of levels.

At the primary station on Sonoma mountain, north of San Francisco, Mr. Davidson observed the phases of the solar eclipse of the 18th of July, using the zenith telescope No. 3. In this service, as also in the preliminaries for observing the Pleiades occultations and in magnetic determinations, which will be again referred to, he had the voluntary and intelligent assistance of Henry B. Hubbard, esq., of Cambridge, Mass.

The observations for latitude at Ross mountain were made chiefly by Mr. A. T. Mosman, the aid, with the zenith telescope No. 3, and in the absence of Assistant Davidson, in consequence of a hurt received at that station. Mr. E. H. Fauntleroy also assisted in them and in determining the azimuth, and the two aids, in conjunction, completed the transit observations for time. These and others at Sonoma mountain and Bodega were made with transit No. 7. Mr. Mosman was detached from the party at the end of March.

For the azimuth at Ross mountain a result was obtained with a probable error of $\pm 0.''2$ in thirty-four sets of six observations each, made on seven nights with the C. S. theodolite No. 37. The azimuth was also determined at the primary station on Sonoma mountain and for the secondary work at Bodega station, the same instruments being used at both. In all, two hundred and four observations were recorded for azimuth, and two hundred and thirty-eight with the transit, exclusive of fifty-four with a sextant for time.

The latitude was determined by four hundred and twenty-five observations of forty-one pairs of stars, and the value of the micrometer by one hundred and eighty-six readings. For the coefficient of refraction thirteen hundred and eighty observations were made, and eight hundred and fifty-one readings of the barometer and thermometers recorded. The value of the level scale divisions was ascertained from ninety-six observations.

Mr. Davidson makes the following remarks in regard to the character of the atmosphere at Sulphur Peak, one of the primary stations occupied by his party last year: "With the zenith telescope I have observed for latitude stars below the eighth magnitude with a small magnifying power and with a diagonal eye piece. The air at that height (3,500 feet) is very clear in summer and remarkably dry, as seen by the shrinking and splitting of boxes that have been many years in use. The last-mentioned condition is evidenced also by differences of twenty to twenty-four degrees between the dry and wet bulb thermometers. Frequently at night while a gale from E.NE. (true) was blowing at the station it would be calm below, or the wind drawing to the north up Russian River valley. At the same time a thick fog would prevail on the coast to the height of thirteen or fourteen hundred feet, while the wind there was blowing fresh from W.NW. or NW."

"The winter season proved very unfavorable for rapid work and for moving. During the first eight days of January rain fell to the depth of twelve inches and a half at Ross mountain, and in the end of March and beginning of April nine inches and a half fell in eight days. In the valleys the amount was much less."

All the computations and reductions connected with the astronomical work and triangulation and magnetic observations to be yet noticed were kept up as the determinations were made, and these, with the original records, making a total of sixty-six volumes, were forwarded to the office by Assistant Davidson. The extended astronomical observations were made by him personally, and his stations of previous years have been joined with the triangulation.

Primary and secondary triangulation north of San Francisco bay, Cal.—At the date of my last annual report a reconnaissance was in progress, under the direction of Assistant Davidson, for extending the primary triangulation on the coast of California northward of Russian river; and

at that time only the station on Ross mountain remained to be occupied to bring the main work complete up to the river just named. Mr. Davidson remained at Sulphur Peak, (see Sketch No. 34,) while his aids, Messrs. E. H. Fauntleroy and A. T. Mosman, were employed about thirty-five miles to the northward in establishing two stations to connect with it and with Ross mountain. Both of the stations selected by them are shown on the progress sketch. The observations on the new signals were at once completed at Sulphur Peak, and with greater difficulty the angular measurements required on them at Ross mountain. Here Mr. Davidson was severely injured while engaged with his party in getting up a signal pole to the station from a gulch near his camp, and was compelled to return to San Francisco. The measurement of horizontal angles and other operations were prosecuted in his absence by the aids of the party.

At Sulphur Peak vertical angles were measured on two objects, at Bodega station on eleven, and at Ross mountain on fifteen, with the vertical circle, C. S. No. 28. The height of Mount Helena was incidentally determined from that station, and an altitude found from the preliminary calculations of 4,343 feet above the ocean level.

In the course of his reconnaissance northward of Ross mountain Mr. Fauntleroy traced the shore-line between Russian river and Walalla mountain, and furnished a sketch to the office, with a report on the reconnaissance. He also posted the heliotropers required for the primary work.

While moving from Ross mountain to the mouth of the river above named Mr. Davidson found much difficulty in transporting his instruments over the intervening ridges, which are entirely impracticable for teams. He acknowledges valuable assistance rendered to him in so doing, and to the party while at Ross mountain by Mr. John H. Chenowith.

Mr. Fauntleroy died suddenly at San Francisco on the 25th of May, in the midst of a career which promised much usefulness to the survey. He had served with Assistant Davidson since his last return to the western coast in 1858, and had acquired much experience in the variety of duties required in traversing a country so devoid of facilities for personal comfort or for travel as the region over which he had been actively engaged.

After being detained in San Francisco two months by his injuries, Mr. Davidson rejoined his party on the 4th of June, and under his direction Mr. Horace Anderson, who had been detailed as aid, erected the signals for a tertiary triangulation between Tomales bay and Salmon creek, to include Bodega bay, (Sketch No. 34.) The reconnaissance for this work had been made, and signals necessary for the secondary and tertiary series of triangles, to embrace the coast north of it to Russian river, were set up by Mr. Mosman previous to his departure for Section XI.

Mr. J. M. Gilliss joined the party at the end of February, and after a period of absence on special duty in Washington Territory returned to it on the 1st of August.

The following are the statistics of the season's triangulation:

Signals erected	24
Objects observed on	71
Angles measured	85
Number of observations	4,949

The horizontal angles were measured with the C. S. theodolite No. 37. Over two thousand observations were recorded in measuring vertical angles.

Assistant Davidson was about to occupy the secondary station, "Redwood," when his report for the season was forwarded. He remarks, in reference to the means employed for securing accuracy in the primary work, that the results show a mean probable error of only $\pm 0.''20$, and that in some cases the probable error in the angular measurements is only $\pm 0.''15$.

All the records and computations connected with the triangulation have been turned in and filed at the office.

Magnetic observations.—In connection with the work of secondary triangulation at Bodega, a magnetic station was occupied by Assistant Davidson, and the absolute magnetic declination, dip, and intensity were determined, as also the values of the instrumental scales. Some observations were undertaken to determine the coefficient of temperature for the deflecting magnet, but the freezing mixture provided for the purpose proved to be deficient.

The magnetic declination was observed also at Ross mountain. At these two stations five hundred and fifty-one observations in all were made with the theodolite magnetometer No. 3 and dip circle No. 5.

Topography of Santa Cruz island, Cal.—The survey of this island, which is one of the Santa Barbara group, was resumed by Sub-Assistant W. M. Johnson at the opening of the working season, and continued until the 9th of September. The statistics of the work done have not yet reached the office.

Towards the end of September the party of Mr. Johnson was transferred to Half Moon bay in the steamer Active, and the plane-table work is now in progress there to fill a gap in the survey of the coast between San Francisco entrance and Monterey bay.

Topography of Petaluma creek, Cal.—The plane-table survey of this tributary of San Pablo bay was commenced by Assistant A. F. Rodgers on the 28th of June. Two sheets were projected for it—one to contain the topography of the upper part of the creek, including the town of Petaluma; and the other the natural features along the banks from Lakeville to its entrance into San Pablo bay. Mr. Rodgers worked on the upper sheet, and by the 10th of September completed all the requisite details. The lower sheet was assigned to Mr. David Kerr, the aid in the plane-table party. Both are now filled, and will be inked in the course of the coming winter. Their limits are shown on Sketch No. 34.

The survey of Petaluma creek is based on the triangulation made by Assistant G. A. Fairfield in 1858. A summary of the plane-table statistics is thus given in the report of Assistant Rodgers:

Shore-line	33 miles.
Marshes, ponds, and sloughs	$233\frac{1}{2}$ "
Roads	33 "
Area, (in square miles)	$30\frac{1}{4}$

The topographical sheet containing the survey of Napa creek was received from Mr. Rodgers in December last, and is now at the Coast Survey office. That branch of San Pablo bay is important as furnishing the only direct means of transportation for the agricultural and mineral resources of one of the largest valleys of the State of California.

The two sheets of the survey of Petaluma creek represent about twelve miles of its course above San Pablo bay.

Topography of Sir Francis Drake's bay, Cal.—This work comprises a survey of about sixteen miles of the coast of California, between Duxbury reef and Point Reyes. The topography includes a belt of about a mile and a half in breadth, and was executed between the 21st of December and the 9th of June by the party of Assistant Rodgers. The details are on three sheets, which connect with each other, and with the local surveys of Ballenas bay and Point Reyes, made in previous seasons. A fourth sheet is now in progress for extending the topography northward from the cape just named in the direction towards Tomales bay.

Sub-Assistant C. M. Bache joined the plane-table party on the 1st of June, and inked the sheets embracing the completed work.

Assistant Rodgers was aided in the field by Mr. Kerr. The following are statistics of the detailed survey of the shore of Drake's bay:

Shore-line of ocean	$16\frac{3}{4}$ miles.
Shores of creeks, etc	$49\frac{1}{2}$ "
Area of topography, (square miles)	32

The limits of the sheets referred to are marked on the progress sketch of the section, (Sketch No. 34.) Tracings of the shore-line contained on them were furnished for the use of the hydrographic party of Commander Alden.

The coast above Duxbury reef presented great obstacles to progress, being mountainous in its character, and broken by sharp ridges and deep intervening ravines.

Assistant Rodgers is now at work on the shores of Tomales bay, above Point Reyes.

Hydrography.—In the course of the season the party of Commander James Alden, U. S. N., Assistant Coast Survey, executed the following surveys in this section with the steamer Active. The localities of work will be referred to in geographical order. The mouth of the Salinas river (Monterey bay) was sounded out between the 1st and 15th of May.

The hydrography of the entrance and approaches of San Francisco bay was extended, and finally completed at intervals during the present year.

At the special request of commissioners having in charge the improvement of navigation in the entrance of San Antonio creek, Commander Alden made a careful re-examination of the Oakland bar, and sounded out the entrance minutely in the latter part of May. A tide-gauge was set up for the reduction of soundings, and observations made for determining the character of the currents in connection with them.

Petaluma creek, (San Pablo bay,) from its entrance upwards to the town of Petaluma, was sounded before the close of the season by the party in the Active. Before leaving the bay hydrographic examinations were made by soundings on the "Tongue shoal," and at "Hog's Back," near the mouth of Sacramento river.

Resuming the coast hydrography north of San Francisco entrance, the in-shore soundings were extended to Point Reyes, including Drake's bay and lagoon, (Sketch No. 35,) and from Point Reyes carried northward to the entrance, and then quite through Tomales bay.

The several localities mentioned will be recognized by Sketch No. 34. An abstract of the soundings made during the season is given below:

Miles run in sounding	356
Angles determined	3,886
Number of soundings	23,837

Two original sheets, containing the soundings made in the harbor of San Pédro and its approaches, and the survey of Humboldt bay, have been received from Commander Alden since the opening of the year. The work at both of these localities was completed last season.

Commander Alden was detached from duty in the Coast Survey at his own request early in October, and will be succeeded by Lieut. Comg. D. D. Porter, U. S. N.

Tidal observations.—Under an arrangement made several years ago satisfactory to the chief of the Engineer Bureau, and by which the services of Lieut. G. H. Elliot, of that corps, became available for the general supervision of the observations on the Western Coast, the self-registering tide-gauges at San Diego and San Francisco have been kept in operation during the surveying year. A temporary station was established at Cape San Lucas, and a series obtained which, though defective, will serve for general purposes of comparison with the results found at the two permanent stations. The records from the gauges kept at San Diego and San Francisco are highly creditable to the observers, Mr. A. Cassidy and Mr. H. E. Uhrlandt.

SECTION XI.

FROM THE FORTY-SECOND PARALLEL TO THE NORTHWESTERN BOUNDARY OF THE UNITED STATES, INCLUDING THE COAST OF THE STATE OF OREGON AND THE COAST OF WASHINGTON TERRITORY.—(SKETCH K, No. 36.)

The following work has been executed in this section since the date of my last annual report:

1. The measurement of a preliminary base and triangulation of Gray's harbor, W. T.
2. Progress in the triangulation of the Gulf of Georgia, W. T., including the measurement of the preliminary base on Sandy Point.
3. The eclipse of July 18 was observed at a station near Steilacoom.
4. A reconnaissance with soundings at the mouth of the Coquille river, Oregon.
5. Tidal observations.

Office-work.—Additions have been made in drawing and engraving to Alden's reconnaissance of the Western Coast, (upper sheet,) and to the progress sketch, and the drawing has been completed for a new edition of the preliminary chart of Washington sound. Progress has also been made in the drawing of a general map and chart to include that sound.

Triangulation of Gray's harbor, W. T.—The party of Sub-Assistant J. S. Lawson reached the entrance of Gray's harbor on the 23d of April in the brig Fauntleroy, and without delay made preliminary arrangements for the triangulation. Mr. Lawson selected a site on the northern side of the entrance, and then measured a preliminary base, finding for its approximate length 1,745 metres. Proceeding from that vicinity, a triangulation was laid out and measured, to include the entire bay, as well its expansions north and south of the entrance as the body of it setting up northward and eastward to the mouth of Chehalis river.

During part of the season Sub-Assistant Lawson was aided in this duty by Mr. A. T. Mosman, who joined his party near the end of March, and after a short absence in July returned to it again when relieved from special duty in the northern part of the section.

The plan of the triangulation of Gray's harbor is shown on Sketch No. 36.

Mr. Lawson secured the ends of the base line temporarily with wooden blocks, pieces of stone of durable kind not being procurable on the shores of the harbor. The line will be remeasured before the ends are marked in the usual way, and observations will be made to determine the latitude and azimuth of the lines of the triangulation.

As the work progressed signals were determined in position for the hydrography, but in consequence of the detention of the steamer Active in Section X, and the detachment before the close of the season of the officer in command, the soundings have not yet been taken up. As already stated, an officer has been detailed to succeed Commander Alden in the charge of the hydrographic party, and the work for which provision has been made will be included in the operations of the coming year. Lieut. Comg. D. D. Porter, U. S. N., is now completing arrangements for taking command of the steamer Active.

Sub-Assistant Lawson reported the completion of the preliminary work on the 1st of September, with the following synopsis of statistics:

Signals erected	36
Stations occupied	22
Angles measured	194
Objects observed on	154
Number of observations	6,018

For the determination of hydrographic and shore-line points four hundred and twenty-eight single readings were taken in addition on secondary signals. The field computations were kept up regularly as the work advanced, and as soon as practicable Mr. Lawson plotted the points of the triangulation and traced in the shore-line of the harbor.

Mr. Alexander Agassiz, who was attached to the party as aid at the outset of the working season, resigned on the 1st of March.

Sub-Assistant Lawson states that while lying off the entrance of the harbor in the Fauntleroy a northerly current of at least a knot and a half the hour was distinctly perceptible. His general remarks in regard to the character of Gray's harbor are contained in the following extracts from his report on the triangulation:

"The Fauntleroy crossed the bar on the last quarter of the ebb in two and a half fathoms, but I am not certain that we were in the deepest water. * * * *

"*Gray's harbor* is very much taken up by sand and mud flats which are bare at low water, and have between them very contracted channels. The effect of these flats was greatly to retard the progress of the triangulation by impeding our movements. In some places they are so extensive and the mud so soft that the stations could be reached only at high water. The whole of the North bay is an extended mud flat somewhat cut up by channels that mark the courses of a few small streams emptying into this part of the harbor. In neither of these is there sufficient water to float a whale-boat."

"Our first anchorage, in three fathoms and a quarter, at a position north of Point Hanson, though pointed out to us as the best, proved to be otherwise. From the end of the growth of trees on Point Brown there is no defence whatever to the force of winds from the northwest and west, and these are the summer trade-winds of this part of the Pacific coast. As these winds at times blow very strong, with the rapid currents of the harbor, a heavy sea is the consequence, making that anchorage not only uncomfortable, but actually unsafe. Independent of this, there is another feature of the place which renders it dangerous as an anchorage. In the entrance of the harbor there is a *middle ground* which is bare at low water. Until the tide rises sufficiently to cover this bank the current sets regularly in the direction of the channel, but then commences a heavy overfall, causing a rip or bore, especially on the large tides, and strong enough to tear vessels from their anchors. This effect happened to our vessel on the night of the 4th of May, and other vessels have met with the same mishap. * * * *

"I consider the South bay as the only safe anchorage near the entrance of the harbor."

"The cursory examination made during the progress of the triangulation inclines me to think that the hydrographic survey will develop many changes that have taken place in the channels since they were first examined. The south channel is impracticable for vessels of any draught, except at high water. There seems to be a middle channel leading into the harbor, but we were unable to determine its capacity."

"For vessels going to the head of Gray's harbor or into the Chehalis river the north channel is the only one to be used. It is very narrow in some places, and to be made available should be buoyed out in its entire length."

The original record of horizontal angles measured by Mr. Lawson at Crescent City harbor, in the lower section of the Western Coast, has been received at the office.

Triangulation of the Gulf of Georgia, W. T.—Sub-Assistant Lawson was still at work in the Gulf of Georgia at the date of my last annual report; and before leaving that vicinity he measured, in addition to the progress then reported in statistics, thirteen angles, using seven additional signals. He also traced about fifteen miles of the shore-line adjacent to his triangulation of the Gulf of Georgia.

Measurement of a preliminary base at Sandy Point, W. T.—After closing the triangulation work of the season in November of last year Sub-Assistant Lawson proceeded to Sandy Point, a narrow neck which projects southward from the main land of Washington Territory, towards the north end of Lummi island, (Sketch No. 36,) and measured a base of 1,181.16 metres. This line connects with the triangulation of the Gulf of Georgia. The measurement was made with the improved apparatus described in Appendix No. 45 of my annual report for 1857.

As reported by Mr. Lawson, the site of the base on Sandy Point is not well adapted for great

accuracy in the determination of its length, part of it running over unstable marsh. In other respects it is devoid of the difficulties that present themselves on the numerous islands lying more nearly central in the triangulation.

Soon after his return to San Francisco last winter, Mr. Lawson sent to the office the originals and most of the duplicates of the journals kept in the field operations of 1858–'59. These are contained in twenty-eight volumes, and comprise the records of horizontal and vertical angles, descriptions of the stations as marked for future reference, and notes of the measurement of the preliminary base at Sandy Point. He has furnished also the field computation derived from the measurements for horizontal angles.

The party in the Fauntleroy is now about to proceed northward and take up the plane-table survey of San Juan island, in Washington sound.

Astronomical observations.—With the concurrence of the Hon. Secretary of the Navy, the services of Lieut. J. M. Gilliss, U. S. N., were tendered to the Coast Survey in May last, for the special object of observing the solar eclipse of the 18th of July, for longitude purposes. His kind offer having been at once accepted, preliminary arrangements were made at the Coast Survey office, and the requisite aids and instruments were placed at his disposal, with instructions to proceed to Washington Territory, and to choose a station as nearly as practicable on the line of the central eclipse. Lieut. Gilliss reached Seattle on the 22d of June, and after a general reconnaissance of that vicinity, and inquiry in regard to others, with a view of procuring the most eligible site for his observations, selected a knoll on Muck prairie, about ten miles S.SE. from Fort Steilacoom. The determinations for time and latitude, with other observations, were successfully made, and the results, as well as the general particulars connected with them, are given in the report of Lieut. Gilliss, which will be found in the Appendix No. 22.

Mr. A. T. Mosman detailed from the party of Sub-Assistant Lawson, and Mr. James Gilliss, from the party of Assistant Davidson, served as aids for this special duty.

Hydrographic reconnaissance of Coquille River entrance, Oregon.—Near the close of the last surveying year Commander Alden detailed a party from the steamer Active to proceed, in charge of Lieut. Jno. G. Mitchell, and make an examination and survey, if practicable, of the Coquille river entrance. The party measured a preliminary base, determined the requisite signals, and traced the shores for some distance, but the fogs and rain prevalent in November prevented the use of the signals for laying down the soundings. Lieut. Mitchell reported that the middle of the channel, for a distance of two miles from the mouth of the river, gave depths varying between twelve and twenty-two feet.

A party from the Active is now engaged in a second examination of the mouth of the Coquille, with a good prospect for success.

Previous to his detachment from the command of the hydrographic party on the Western Coast, at his own request in October last, Commander Alden sent to the office a sheet containing the hydrography of the entrance to Haro and Rosario straits, and the sheet of soundings made at the close of last season in the Gulf of Georgia.

Tidal observations.—One of the self-registering gauges in the general charge of Lieut. G. H. Elliot, U. S. Engineers, as stated under the head of Section X, has been kept in excellent working order by Mr. Louis Wilson, and the year's series obtained from it is very satisfactory.

Office-work.—The Coast Survey office has continued, during the past year, to be in charge of Captain W. R. Palmer, U. S. Topographical Engineers, the effect of whose experience and careful administration may be traced in all its divisions. Lieutenant A. P. Hill, U. S. A., has acted as general assistant. During occasional absences of Capt. Palmer, Lieut. Hill has been in temporary charge of the office, and has shown his usual decided efficiency.

The report of Captain Palmer (Appendix No. 19) is followed by those of the chiefs of the several divisions of the office, viz: 1. *The Hydrographic Division;* 2. *The Computing;* 3. *The Tidal;* 4. *The Drawing;* 5. *The Engraving;* 6. *The Photographing and Electrotyping;* 7. *The*

Miscellaneous Division. The details show minutely the occupation of each person, and the progress resulting from their joint labors. The improvements made and making are of a striking character, and are carefully stated. Captain Palmer, Lieutenant Wilson, and Mr. Mathiot give interesting statements of the application of photography, which has now been systematized in its minutest details.

The general occupation in the different divisions has been as follows:

Hydrographic Division.—Under Commander S. S. Lee and Lieut. Silas Bent, U. S. N., important revisions have been made of hydrographic work and of the charts resulting from it, original as well as reduced, sailing directions, dangers, &c., &c. *Mr. A. Balbach* has been attached to the division as draughtsman, and has executed the details under the direction of Lieut. Bent. These include the verification of orginal sheets, the revision of engraved sheets, the plotting of sailing lines and current stations, and the correction of positions of buoys, light-vessels, &c. *Mr. L. Karcher* has been employed since April in making projections for the hydrographic parties, and in replotting preliminary hydrographic work. *Mr. W. B. McMurtrie* has made projections and views for charts, and part of the season was employed in revising sheets of special localities. *Messrs. W. S. Simpson and Orton Williams* have been assigned to the division for practice in hydrographic drawing in advance of taking duty with the parties afloat.

Computing Division.—Assistant C. A. Schott has been in charge as heretofore, and has fully maintained the efficiency required in this important branch of the office. He took the field in August and September, and determined the magnetic elements at several stations on the coast, and has, in addition to his general duties, contributed for this report several papers of interest, copies of which will be found in the Appendix, (Nos. 25, 28, 29, 36, 37, and 38.) Of the computers attached to the office, Assistant T. W. Werner has been engaged in the reduction of triangulations and azimuths; Mr. E. Nulty on reductions of azimuths and latitudes, and Mr. J. Main in the revision of various astronomical computations, and in reducing magnetic observations. He also had charge of the division during Mr. Schott's temporary absence on field duty.

Mr. G. Rumpf has been engaged in the revision of geodetic computations, and in adjusting triangulations by the method of least squares. Mr. J. Wiessner was reassigned to duty in August last, and has since been employed in adjusting triangulations and in miscellaneous computing.

Mr. W. D. Storke was, for several months, on field duty, and while connected with the division made reductions of triangulation work. Mr. B. H. Todd has been engaged in various astronomical and geodetic computations, and assisted in reducing results from the larger triangulations.

Mr. J. T. Hoover acted as clerk to the division in the early part of the year, and also assisted in preparing lists of geographical positions. He is replaced by Mr. J. H. Patton, who has since performed the clerical duty and aided in special observations.

Assistant A. S. Wadsworth and Sub-Assistant C. Fendall were temporarily attached to the division after their return from field-service at the south. Mr. H. Ledyard was attached for a short period and engaged in clerical duty.

Tidal Division.—The labors of this division, which have been, as heretofore, conducted by Assistant L. F. Pourtales, are stated in the Appendix before referred to.

Mr. Pourtales has continued, incidentally, the investigation of specimens of soundings, and has made developments of much interest in this branch of research.

The force of the division has been employed as follows: Mr. R. S. Avery on discussions relative to the application of formulæ, and, during occasional absences of Mr. Pourtales, he has been in charge of the division. Mr. J. Downes has continued the graphical decompositions, reductions, and comparisons. Mr. J. W. Donn is engaged in verifying the records and

corresponds with the observers. Mr. C. Balmain and Mr. J. R. Gilliss have made graphical decompositions, and M. Thomas and S. D. Pendleton have been employed in miscellaneous reductions.

Drawing Division.—*Lieut. Thomas Wilson, U. S. A.*, has continued in charge of this division, and its progress, together with the great assistance which reduction by photography has rendered to it, is fully treated in his report, (Appendix No. 19.) The distribution of work has been as follows: *Assistant W. M. C. Fairfax*, until within a short period of his lamented decease, which occurred on the 8th of August, and to which reference has been made in the introduction to my report, was engaged upon the most elaborate topographical reductions. *Assistant M. J. McClery* has also been employed upon work of a similar character, and has filled in topography upon photographed outline. *Mr. E. Hergesheimer* has assisted in the compilation of new instructions for draughtsmen and engravers, and has had charge of the preparation and generalization of sheets intended for the photograph, and the verification of the negatives of the same. Before entering upon these duties he was engaged upon reductions of topography and hydrography. *Mr. A. Lindenkohl* on topographical and hydrographical reductions of various scales, projects, projections, verifications, and progress sketches. *Mr. W. P. Schultz*, during the short time he was employed, worked on projects, projections, progress sketches, diagrams, and preliminary charts. *Mr. L. D. Williams* on fine reductions of topography and hydrography, verifications and projections. He also made additions to the Congress map. *Mr. A. Strauz* has been employed on hydrographic reductions and projections for field parties. *Mr. W. T. Martin* has worked on topographical drawings, and has filled in topography upon outline reduced by photography. *Mr. J. J. Ricketts* and *Mr. L. Karcher*, during part of the season, made hydrographic reductions for the smaller scale charts. The former, during the year, was assigned to duty in the field, and the latter transferred to the Hydrographic Division. *Mr. S. B. Linton* has made reductions of various kinds, progress sketches, projections, diagrams and tracings, and has executed lettering. *Mr. F. Fairfax* is employed on preliminary charts, in tracings, and in miscellaneous duties. *Mr. B. Hooe* on tracings generally, and *Mr. W. Fairfax* and *Mr. A. J. De Zeyk* on the same during part of the year. *Messrs. J. W. Maedal* and *W. H. Gardner* have made tracings of original sheets to be used in photography.

Engraving Division.—The duties of this division have been conducted by *Lieut. J. R. Smead, U. S. A.*, assisted by *Mr. Edward Wharton.* The distribution of the work to the engravers has differed but little from that of the previous year. *Mr. G. McCoy* has been engaged upon topography and views for charts; *Mr. John Knight* on first class lettering; *Messrs. A. Rolle, J. Enthoffer, A. Blondeau*, and *H. C. Evans* on topography; *Messrs. A. Sengteller, W. Phillips, G. B. Metzeroth*, and *A. Maedal* on topography and sand; *Mr. H. S. Barnard* on sanding; *Mr. J. C. Kondrup* on first class outlines; *Mr. J. V. N. Throop*, up to the time of his death, upon lettering for harbor charts; *Messrs. E. A. Maedal, W. Ogilvie, A. Petersen, W. Langran*, and *C. T. Klackring* upon lettering and figures; *Messrs. R. F. Bartle, F. W. Benner*, and *W. A. Thompson* upon topography, sand, and miscellaneous work; *Mr. E. H. Sipe* upon lettering; and *Messrs. M. L. Wells* and *J. G. Thompson* upon progress sketches and miscellaneous work.

Photograph and Electrotype Division.—The details of the work done in this branch of the office will be found in the report of *Mr. George Mathiot*, (Appendix No. 19,) who is in charge of the division. Mr. Mathiot has continued his labors in photography, and, by substituting glass for paper in the reductions, has overcome the effect of hygrometric changes on the paper photograph. The process has been made a regular office method, and the short time that it has been in use has proved its economy both in time and expense. It allows the engraving to go on steadily, each plane-table sheet being reduced separately and the junctions being made on the copper plate. Estimates of the chiefs of the Drawing and Engraving Divisions show that the cost of publication of a chart by this method will be at least one-third less than that

by hand reduction. The method is detailed in Mr. Mathiot's report. Three of the most elaborate charts of the survey are now engraving from the photographic reductions.

The photograph has been made available in several cases for forming projects for charts, the facility with which a drawing can be enlarged or deduced being well adapted for this purpose, as detached sketches on different scales can be readily combined into one. Mr. Mathiot has had the intelligent assistance of *Mr. David Hinkle* in the various duties of the division.

Miscellaneous Division.—Lieut. J. R. Smead, U. S. A., has, in addition to his charge of the engraving, also had the care of this division up to the first of October, when he was relieved by *Lieut. N. H. McLean, U. S. A.* The various duties classed under this head have been well and actively performed during the past year, and the delicate responsibility of curtailing the number of those who have annually looked forward to the reception of the reports, caused by the diminished number of extra copies ordered by the Congress of 1858–'59, has been judiciously accomplished. The distribution of the printed maps and charts during the year called for over six thousand copies, and of the annual reports and sketches five thousand and seventy-seven. The duty of assistant in this division has been successively performed by *Mr. V. E. King*, *Mr. T. B. Alexander*, *Mr. C. C. Callan*, and now by *Mr. M. Maynadier*. *Mr. J. Rutherdale*, printer, aided by *Mr. J. Barrett*, has printed all the charts and sketches required for office use and for distribution. *Mr. M. Mertz* backs all the paper required for the field parties, and also devotes a good deal of time to securing from further damage the older and much-used records in the archives. *Mr. J. Vierbuchen*, master machinist, and *Mr. A. Yeatman*, master carpenter, have kept their respective shops up to the standard requisite to meet all the calls made upon them.

Commander S. S. Lee has continued to discharge acceptably, and with decided advantage to the survey, the duties of hydrographic inspector, and has attended personally to the fitting out of all the vessels used in the survey.

Assistant L. F. Pourtales in tidal discussions, Professor W. P. Trowbridge in that of the Gulf Stream, and Assistant C. A. Schott in various questions which came up during the year, have rendered valuable service.

The duties of general disbursing agent have been discharged with his usual care, industry, and faithfulness by Samuel Hein, esq.

The principal clerk in the Superintendent's office has, with added experience, continued in the same effective track of duty; and in my service in the field Hugh McHenry, esq., has been very attentive and industrious.

Respectfully submitted.

A. D. BACHE,
Superintendent U. S. Coast Survey.

Hon. PHILIP F. THOMAS,
Secretary of the Treasury.

APPENDIX.

APPENDIX No. 1.

Distribution of the parties of the Coast Survey upon the coasts of the United States during the surveying season of 1859–'60.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION I.				
From Passamaquoddy bay to Point Judith, including the coast of Maine, New Hampshire, Massachusetts, and Rhode Island.	No. 1	Geodetic, astronomical, and magnetic observations.	A. D. Bache, Superintendent; G. W Dean, assistant; J. H. Toomer and R E. Halter, sub-assistants; H. W. Bache, R. H. Talcott, and H. W. Longfellow, aids.	Gunstock mountain, Belknap county, N. H.; Unkonoonuc mountain, Hillsborough county, N. H.; and Wachusett mountain, Worcester county, Mass., occupied for completing the primary triangulation of the coast of New England. Determinations made at the first and last station for latitude, azimuth, and the magnetic elements. (See also Section VII)
	2	Secondary triangulation.	C. O. Boutelle, assistant; Lt. George Bell, U. S. A., assistant.	Secondary triangulation of the Cobscook and adjacent parts of Passamaquoddy bay. (See also Sections II and V.)
	3	Secondary triangulation.	F. P. Webber, sub-assistant; J. Kincheloe and G. U. Mayo, aids.	Triangulation of Frenchman's bay, Me., extending from Pigeon Hill to Mt. Desert, and northward to the town of Sullivan. Connection of the work with the primary base on Epping Plains.
	4	Secondary and tertiary triangulation.	J. A. Sullivan, sub-assistant, (part of season;) G. A. Fairfield, assistant, (part of season;) McLane Tilton and J. D. Bradford, aids.	Completion of secondary triangulation below Camden, Me., and determination of topographical points for the survey of the shores and islands in the lower part of Penobscot bay, including Rockland harbor. (See also Section VI.)
	--------	Secondary triangulation.	F. P. Webber, sub-assistant; J. Kincheloe and G. U. Mayo, aids.	Triangulation of the dependencies of Muscongus bay completed, including the entrances of the St. George, Medomak, and Damariscotta rivers, Me.; also Merrymeeting bay and the Androscoggin river to Brunswick. (See also Section V.)
	5	Topography.......	I. Hull Adams, assistant, (part of season;) Charles Ferguson, sub-assistant.	Plane-table survey of the shores of Sheepscot river completed, and progress made in the topography of Back river and Woolwich peninsula. (See also Section VI.)
	6	Topography.......	R. M. Bache, assistant......	Details of topography nearly completed on the shores of Merrymeeting bay.
	7	Topography.......	A. W. Longfellow, assistant.	Plane-table survey of Harpswell Neck completed, including the neighboring islands of Mericoneig sound, Casco bay.

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION I—(Continued)	No. 8	Topography	H. L. Whiting, assistant; C. Rockwell, aid; Chas. Hosmer, aid.	Special resurvey of islands in Boston harbor for commissioners.
	9	Topography	W. H. Dennis, sub-assistant.	Special survey for commissioners across Cape Cod peninsula from the mouth of Scusset river to Back River harbor, Mass.
	10	Topography	A. M. Harrison, assistant; P. C. F. West, sub-assistant; A. W. Thompson, aid; W. W. Harding, aid.	Plane-table survey of the shores of Cape Cod bay continued from Barnstable harbor westward to the vicinity of Scusset river.
	11	Hydrography	Lieut. Comg. T. S. Phelps, U. S. N., assistant.	In-shore hydrography of the coast of Maine extended across the entrance, and including the approaches of Muscongus bay, between Manhegan and Damiscove islands. Jeffrey's bank thoroughly developed by soundings. (See also Section VII.)
	12	Hydrography	Lieut. Comg. J. P. Bankhead, U. S. N., assistant.	Hydrography of the lower part of the Damariscotta river, Me., completed and connected with in-shore work. (See also Section V.)
	13	Hydrography	Lieut. Comg. John Wilkinson, U. S. N., assistant.	Jeffrey's ledge sounded by traverses, and off-shore line run from Cape Ann to Seal island, N. S. Re-examinations made in Salem harbor and Lynn harbor, Mass. Special hydrography executed in Boston inner harbor for the city commissioners. Cape Cod bay, in the vicinity of the mouth of Scusset river, sounded for commissioners. (See also Section VI, Gulf Stream, and Section VIII.)
	....	Hydrography	Lieut. Comg. T. S. Phelps, U. S. N., assistant.	Development of a new and extensive shoal found eastward and southward of Davis' south shoal, and determination of the position of Asia rip. (See also Section VII.)
	14	Tidal and current observations.	H Mitchell, assistant; W. T. Bright, L. M. Johnson, and E. P. Heberton, aids.	Special observations on the currents for developing the causes of change in the depth of Boston harbor. Investigation of the character of tides and currents near the mouth of Scusset river, (Cape Cod bay,) and in Back River harbor, (Buzzard's bay.) (See also Section VIII.)
	15	Magnetic observations.	Charles A. Schott, assistant; A. S. Wadsworth, assistant.	Declination, dip, and intensity determined at Provincetown, Wellfleet, and Chatham, (Cape Cod peninsula.) (See also Section II)
	16	Magnetic and tidal observations.	G. B. Vose	Magnetic observations made monthly for declination, dip, and intensity at Eastport, Me.; tides observed with self-registering gauge in connection with meteorological observations.
	....	Tidal observations	T. E. Ready	High and low waters observed at the dry dock, Charlestown navy yard, Mass.

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations:	Persons conducting operations.	Localities of operations.
SECTION II.				
From Point Judith to Cape Henlopen, including the coast of Connecticut, New York, New Jersey, Pennsylvania, and part of Delaware.	No. 1	Reconnaissance....	C. O. Boutelle, assistant....	Reconnaissance for stations to connect the primary triangulation in Massachusetts and Rhode Island with that in Connecticut and New York by direct course from the Epping base. (See also Section V.)
	2	Triangulation	Edmund Blunt, assistant; Lieutenant W. G. Gill, U. S. A., assistant	Triangulation of Hudson river, N. Y., completed by extension from New Baltimore northward to the vicinity of Troy.
	3	Topography.......	John Mechan, sub-assistant; F. R. Hassler, aid.	Topography of the shores of Hudson river completed above Hastings to Tarrytown and Piermont, including those villages and Irvington and Rockland. (See also Section IV.)
	4	Topography.......	F. W. Dorr, sub-assistant...	Supplementary details of topography in the vicinity of Williamsburg and Rockaway, L. I., to complete the topography of New York bay and harbor. (See also Section VI.)
	5	Hydrography	Lieut. Comg. C. M. Fauntleroy, U. S. N., assistant.	Hydrography of the Hudson river, continued last season from Fishkill upwards to Poughkeepsie,° and this season extended from Poughkeepsie northward to Rhinebeck. (See also Section V.)
	6	Hydrography	Lieut. Comg. J. Wilkinson, U. S. N., assistant.	Determination of the position of the buoy at Sandy Hook shoal relative to its former position. (See also Sections I, VI, Gulf Stream, and Section VIII.)
	7	Hydrography	Lieut. Comg. Alex. Murray, U. S. N., assistant.	Re-examination of the False Hook channel, entrance to New York bay, and determination of a rocky spot eastward of the Sandy Hook light vessel. (See also Sections IV, V, and VI.)
	8	Magnetic observations.	Charles A. Schott, assistant; A. S. Wadsworth, assistant.	Magnetic declination, dip, and intensity determined at Sag harbor, Mount Prospect, and Fire Island beach, L. I., and at Barnegat, Long Beach, and Atlantic City, N. J. (See also Section I.)
	....	Tidal observations.	R. T. Bassett..............	Series continued with the self registering gauge at Governor's Island, (New York harbor,) and with the box-gauge at Brooklyn, L. I.
SECTION III.				
From Cape Henlopen to Cape Henry, including the coast of part of Delaware, and the coast of Maryland and part of Virginia.	1	....	George D. Wise, assistant...	Examination of and additional marks placed to secure stations used in the triangulation of Chesapeake bay. (See also Section VII.)
	2	Secondary triangulation.	John Farley, assistant; S. A. Wainwright, sub-assistant.	Supplementary work near Nottingham; completing the triangulation and shore-line survey of Patuxent river, Md.; triangulation of the Potomac river extended from Piney Point upwards, and including Britton's bay.

° Inadvertently omitted in Appendix of last annual report.

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION III—(Continued.)	No. 3	Topography	C. T. Iardella, sub-assistant; T. C. Bowie, aid.	Connection by plane-table survey between the shore of Chincoteague bay and the head of Pocomoke sound, Md. (See also Section VI.)
	4	Topography	I. Hull Adams, assistant; J. L. Tilghman, aid, (part of season.)	Supplementary topography to complete details on the south side of the mouth of Elk river, Maryland. Shore-line run between Town Point and Leonard's creek, completing preliminary survey of the Patuxent river; and additional details to complete the topography of St. Mary's river, Maryland. (See also Section I.)
	5	Topography	S. A. Wainwright, sub-assistant.	Shore-line traced on the south side of the Potomac river, in the vicinity and including the mouth of Coan and Yeocomico rivers, Virginia.
	....	Topography	Geo. D. Wise, assistant; O. Hinrichs, aid.	Topography of the shores of North river and Ware river, at the head of Mobjack bay, nearly completed. (See also Section VII.)
	6	Hydrography	Com'dr W. T. Muse, U. S. N., assistant.	Hydrography of the Potomac river, extended from the entrance upwards to Blackstone island and in that vicinity, including Britton's bay and St. Clement's bay.
	7	Magnetic observations.	C. A. Schott, assistant	Determination of instrumental constants in connection with the magnetic elements at Washington, D. C. (See also Sections I and II.)
	....	Tidal observations .	J. W. Donn, M. C. King	Regular series continued with the self-registering gauge at the Washington navy yard, D. C., and series kept up at Old Point Comfort, Va.
	....	Views	W. B. McMurtrie	Sketch of the coast in the vicinity of Cape Henry, to accompany general coast chart No. IV.
SECTION IV. From Cape Henry to Cape Fear, including part of the coast of Virginia and N. Carolina.	1	Primary triangulation.	Capt. T. J. Cram, U. S. top'gl engineers, assistant; A. S. Wadsworth, assistant.	Primary triangulation of the southwestern part of Pamplico sound, N. C., extending to Royal Shoal rock; and station occupied, in connection with the Bodies island base.
	2	Topography	John Mechan, sub-assistant; F. R. Hassler, aid.	Supplementary topography to connect work north and south of Oregon inlet, coast of North Carolina; and detailed plane-table survey of the peninsula westward from Cape Hatteras, including also the upper part of the island between Hatteras and Ocracoke inlets, forming part of the shore of Pamplico sound. (See also Section II.)
	....	Reconnaissance	John Mechan, sub-assistant; F. R. Hassler, aid.	Soundings in Coanjock bay, and up the North river, from the head of Currituck sound to Weir Point, with observations of the changes of level in the sound. (See also Section II.)

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION IV—(Continued.)	No. 3	Hydrography	Lieut. Comg. Alex. Murray, U. S. N, assistant.	Line of soundings from Cape Henry to Cape Lookout, and thence to Charleston, traversing off-shore hydrography of this section. (See also Sections V, VI, and Gulf Stream.)
		Views	W. B. McMurtrie	Cape Hatteras and vicinity, drawn in perspective for off-shore chart.
SECTION V.				
From Cape Fear to St. Mary's river, including the coast of South Carolina and Georgia.	1	Primary & secondary triangulation and topography.	C. P. Bolles, assistant; O. Hinrichs, aid.	Triangulation of the coast of North Carolina completed between Shallotte inlet, and the detailed topography executed from Tubbs' inlet westward and southward to the vicinity of the State boundary at Little river, S. C.
	2	Primary and secondary triangulation.	C. O. Boutelle, assistant; C. H. Boyd, aid.	Primary triangulation carried from the Edisto base southward to Port Royal sound, and connected with secondary work, embracing the coast of South Carolina and St. Helena sound. Triangulation completed to connect the waters of the sounds through the Coosaw, Morgan, and Beaufort rivers. (See also Sections I and II.)
	3	Secondary triangulation.	F. P. Webber, sub-assistant; J. Kincheloe, aid.	Secondary triangulation of the coast of Georgia extended southward and westward from Altamaha sound; joined with the survey of St. Simon's entrance, and carried over Jekyl and St. Andrew's sounds. (See also Section I.)
	4	Topography	C. Rockwell	Details of topography completed between Port Royal sound and Savannah river, embracing Hilton Head island; Pinckney's, Bull's, Dawfuskie, Terrapin, and other islands; the shores of the Inland Passage, Calibogue sound, and Cooper river, with parts of the shores of May river, New river, and smaller branches of the sound. (See also Section I.)
	5	Topography	H. S. Du Val, sub-assistant; J. D. Bradford, aid.	Plane-table survey commenced on the shores of Wassaw sound, Georgia. Details of topography continued in the middle parts of Ossabaw island.
	6	Hydrography	Lieut. Comg. J. P. Bankhead, U. S. N., assistant.	Supplementary off-shore soundings between Charleston, S. C., and Fernandina, and extending from the coast of South Carolina and Georgia to the Gulf Stream. Re-examination of Maffitt's channel, Charleston harbor, and complete hydrographic survey of the Coosaw, Morgan, and upper part of Beaufort river, S. C. (See also Section I.)
	7	Hydrography	Lieut. Comg. C. M. Fauntleroy, U. S. N., assistant.	Hydrography of Ossabaw sound, Georgia, completed, including the bar and approaches, the Vernon river up to Montgomery, and parts of the Great and Little Ogeechee rivers, Wassaw creek, and the Romerly and Florida passages. (See also Section II.)

APPENDIX No. 1.—Continued.

Limits of sections.	Parties	Operations.	Persons conducting operations.	Localities of operations.
SECTION V—(Continued.)	....	Hydrography	Lieut. Comg. J. P. Bankhead, U. S. N., assistant.	Altamaha sound, Georgia, surveyed upwards to Mud river, in connection with in-shore hydrography of the coast of Georgia, abreast of St. Simon's island, and Hampton river sounded. (See also Section I.)
	No. 8	Hydrography	Lieut. Comg. Alex. Murray, U. S. N., assistant.	Line of soundings run coastwise from Charleston harbor to Cape Lookout, N. C., and others along the coast of South Carolina and Georgia, traversing off-shore hydrography between Charleston and Fernandina. (See also Sections IV, VI, and Gulf Stream.)
	....	Tidal observations.	W. R. Herron..............	Self-registering tide-gauge kept in operation at the custom-house wharf, Charleston, South Carolina.
SECTION VI. From St. Mary's river to St. Joseph's bay, including the eastern and part of the western coast of the Florida peninsula, with the Florida reefs and keys.	1	Triangulation	Captain M. L. Smith, United States topographical engineers, assistant; Lieut. R. G. Cole, U. S. A., assistant; Lieut. O. D. Green, U. S. A., assistant.	Lines opened and cleared for continuing the air line triangulation across the Florida peninsula from Waldo westward to Gainsville, in the direction towards Cedar Keys.
	2	Triangulation.....	Benjamin Huger, jr., sub-assistant; W. H. Dennis, sub-assistant.	Connection made between the triangulation of St. John's river, Fla., and that of St. Augustine harbor, including the course of North river, and triangulation of the northern part of Matanzas river.
	3	Triangulation and topography.	Charles Ferguson, sub-assistant; Horace Anderson, aid.	Triangulation and plane-table survey of Indian River inlet, Fla., completed, and preliminary soundings made. (See also Section I.)
	4	Triangulation	G. A. Fairfield, assistant; P. C. F. West, sub-assistant.	Connection over the waters of Chatham Bay, inside of Florida reef, by triangulation from Shell key, (Barnes's Sound,) southward and westward to Pigeon key, and completing the reef triangulation.
	5	Triangulation	Lieut. W. R. Terrill, U. S. A., assistant; Lieut. George Bell, U. S. A., assistant; W. S. Edwards, sub-assistant; J. L. Tilghman, aid.	Triangulation completed in the upper part of Charlotte harbor, Fla., including the adjacent Gulf coast to Boca Nueva and the lower part of Peas creek.
	6	Topography	F. W. Dorr, sub-assistant; McLane Tilton, aid; H. W. Bache, aid.	Complete topographical survey of the harbor and city of St. Augustine, Fla., and coast approaches, with the shores of the San Sebastian, Matanzas, and North rivers, adjacent to the harbor. (See also Section II.)
	7	Topography.	C. T. Iardella, sub-assistant.	Shores of Charlotte harbor, Fla., surveyed north of Pine island, with the lower parts of Myakka river and Peas creek, nearly completing the topography of the harbor and its approaches. (See also Section III.)

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION VI—(Continued)	No. 8	Hydrography	Lieut. Comg. Alexander Murray, U. S. N., assistant.	Hydrography of St. Augustine harbor, Fla , completed, including the bar and approaches, and the adjacent parts of the North, Matanzas, and San Sebastian rivers. Development of a four-fathom bank northeast of Indian River inlet, and lines of soundings run coastwise to Fernandina to traverse off-shore hydrography. (See also Section IV and V, and Gulf Stream)
	9	Hydrography	Lieut. Comg. John Wilkinson, U. S. N., assistant.	Soundings extended along the outside of Florida reef from Lower Matacumba, southward and westward, to Grassy key. (See also Section I, Gulf Stream, and Section VIII.)
	10	Magnetic observations.	W. P. Trowbridge, assistant; S. Walker, aid, (part of season ;) G. D. Allen.	Station established at Key West for the continuous record by photography of the variations of magnetic declination and intensity, with monthly observations for the absolute values of the magnetic elements.
	....	Tidal observations .	J. A. Walker, H. Benners...	Series continued with self-registering tide-gauges at Fort Clinch and Tortugas.
	....	Views............	W. B. McMurtrie	Drawings of views for charts of the Florida reef. (See also Section VII.)
GULF STREAM.......	....	Hydrography......	Lieut. Comg. Alexander Murray, U. S. N., assistant; Lieut. Comg. John Wilkinson, U. S. N., assistant.	Sections run across the Gulf current, from Indian River inlet and Gilbert's bar eastward to the Bahama bank, and line for depth and temperature carried southwest from the Tortugas, and thence to the coast of Cuba. (See also Sections I, II, IV, V, VI, and VIII.)
SECTION VII.				
From St. Joseph's bay to Mobile bay, including part of the western coast of Florida and the coast of Alabama.	1	Astronomical, telegraphic, and magnetic observations.	G. W. Dean, assistant; Edward Goodfellow, assistant; A. W. Thompson, aid ; W. D. Storke, aid.	Telegraphic determinations at Apalachicola, Fla., Eufaula, Ala., and Macon, Ga , for differences of longitude ; with observations for latitude, azimuth, and the magnetic elements at Apalachicola, and for latitude and the magnetic elements at Eufaula. (See also Section I.)
	2	Triangulation	G. H. Bagwell, sub-assistant ; M. O. Hering, aid.	Coast triangulation along the western side of Florida peninsula, extended from Bayport southward to Tiger Point, near the Anclote keys.
	3	Triangulation	S. C. McCorkle, sub-assistant; Rufus King, jr., aid.	Triangulation east and west of St. Mark's harbor, Fla., completed to Ocilla River entrance and Southwest cape, and that of St. George's sound extended westward through St. Vincent's sound to Cape San Blas.
	4	Triangulation	F. H. Gerdes, assistant; Clarence Fendall, sub-assistant.	Triangulation completed in Santa Maria de Galvez and East bays, Fla ; connected also with that of Pensacola harbor, and carried northward over Blackwater bay to Robinson's Point.

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION VII—(Continued)	No. 5	Reconnaissance and triangulation.	F. H. Gerdes, assistant; J. G. Oltmanns, sub-assistant; G. U. Mayo, aid.	Preliminary base measured at the entrance of Perdido bay, and triangulation commenced in the lower and upper reaches below Soldier's creek. (See also Section VIII.)
	6	Topography	N. S. Finney, sub-assistant	Topography completed at the entrances of the We-thlocco-chee and Homosassa rivers, Fla., and joined north and south with finished plane-table work.
	7	Topography	G. D. Wise, assistant	Details of coast topography executed between Ocilla river and St. Mark's harbor, Fla., and westward of St. Mark's harbor, completing the shores of Oyster and Dickerson's bays and part of Crooked river. (See also Section III.)
	....	Topography	F. H. Gerdes, assistant; Clarence Fendall, sub-assistant.	Plane-table survey of the shores of Santa Maria de Galvez and East bays, embracing also the shores of Blackwater bay, northward to the mouth of Yellow river. (See also Section VIII.)
	8	Hydrography	Lieut. Comg. J. J. Guthrie, U. S. N., assistant.	Hydrographic resurvey of the Sea-Horse, North West, and North Key channels into Cedar Keys harbor, Florida. Soundings carried from Sea-Horse reef on a line southward to Tampa bay, and from the reef due west nearly to the meridian of Pensacola, and thence northward into port. (See also Section VIII.)
	9	Hydrography	Lieut. Comg. T. S. Phelps, U. S. N., assistant.	Apalachicola harbor, Florida, thoroughly sounded in connection with the hydrography of the adjacent parts of St. George's sound, completing work eastward to Cat Point, and supplementary soundings made along shore from South-west Cape to Crooked river.
	....	Hydrography	Lieut. Comg. T. S. Phelps, U. S. N., assistant.	Hydrography of Santa Maria de Galvez bay completed, including East bay. Soundings extended in Blackwater bay northward to Eagle Point, and in Escambia bay from Pensacola harbor upwards to Live Oak Point. (See also Section I.)
	....	Tidal observations	A. C. Mitchell	Series with self-registering tide-gauges at St. Mark's, Florida, Dog island, New inlet, St. Vincent's island, and at Warrington navy yard. (See also Section VIII.)
	....	Views	W. B. McMurtrie	Coast features drawn for charts of Cedar keys, St. George's sound, and Pensacola harbor. (See also Section VIII)
SECTION VIII. From Mobile bay to Vermilion bay, including the coast of Alabama and Mississippi, and part of the coast of Louisiana.	1	Triangulation	Stephen Harris, sub-assistant; R. E. Halter, aid; C. S. Peirce, aid.	Triangulation extended from Point Fortuna, Louisiana, southward and eastward across Isle au Breton sound, and connected with that of the Mississippi delta.
	2	Triangulation	J. G. Oltmanns, sub-assistant; G. U. Mayo, aid.	Triangulation westward from Côte Blanche island, Louisiana, completing preliminary work in Côte Blanche bay. (See also Section VII.)

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION VIII—(Continued.)	No. 3	Topography	Malcolm Seaton, sub-assistant; W. W. Harding, aid.	Detailed topography of north shore of Lake Pontchartrain, Louisiana, from Bayou Bonfouca westward to a station beyond Ragged Point, and of the south shore from Bayou Coushon to Bayou Tchoupitoulas.
	4	Topography and magnetic elements.	F. H. Gerdes, assistant; J. G. Oltmanns, sub-assistant; C. Fendall, sub-assistant; G. U. Mayo, aid.	Plane-table survey completed of the eastern part of the Mississippi delta, embracing Passe à Loutre and the North, Northeast, and Southeast Passes, with the intermediate bays and the shores of Bay Rondo. Magnetic elements determined at three stations on the delta. (See also Section VII.)
	....	Topography and magnetic observations.	J. G. Oltmanns, sub-assistant; G. U. Mayo, aid.	Topography of Côte Blanche bay from Côte Blanche island westward, and opposite shore of Marsh island, completing the preliminary survey of the bay. Magnetic elements determined at Côte Blanche island. (See also Section VII.)
	5	Hydrography	Lieut. Comg. John Wilkinson, U. S. N., assistant.	Resurvey of Mobile harbor, including the lower parts of the Mobile, Spanish, and Tensaw rivers, and reconnaissance through the channel of Mobile bay to the Lower Fleet. (See also Sections I and IV and Gulf Stream.)
	6	Hydrography	Lieut Comg. J. J. Guthrie, U. S. N., assistant.	Passe à Loutre, Northeast, North, and Southeast Passes of the Mississippi river thoroughly sounded, from their respective bars to the head of the passes. (See also Section VII.)
	7	Tides and currents.	H. Mitchell, assistant; W. T. Bright, aid; L. M. Johnson, aid.	Special observations on the tides and currents of Mobile bay and harbor at stations on the outer bar, in the Upper Fleet, and at the mouth of Alabama river, with current observations on Dog Island bar, Choctaw bar, and also at the mouth of Spanish river. (See also Section I.)
	....	Tidal observations.	A. C. Mitchell	Series commenced with self-registering tide-gauges at Passe à Loutre and Southwest Pass, (Mississippi delta,) and at Isle Dernière. (See also Section VII.)
	....	Views	W. B. McMurtrie	Perspective drawings of Chandeleur Island light and its vicinity, and of Passe à Loutre entrance and light for charts. (See also Sections III, IV, VI, and VII.)
SECTION IX. From Vermilion bay to the Rio Grande boundary, including part of the coast of Louisiana and the coast of Texas.	1	Triangulation	Sam'l A. Gilbert, assistant; Charles Hosmer, aid.	Extension of work coastwise from Aransas Pass, southward and westward to Laguna Madre, and triangulation of Corpus Christi and Nueces bays, Tex.

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION IX—Continued.	No. 2	Topography	W. S. Gilbert, sub-assistant; T. C. Bowie, aid.	Plane-table survey of the shores of San Antonio, Musquit, and St. Charles's bays, Tex., completed, including also St. Joseph's island, or the outer coast of Texas between Matagorda island and Aransas Pass; part of Mustang island; and the reefs and shell banks, with part of the shores of Aransas bay.
	3	Hydrography	Lieut. Comg. W. Ronckendorff, U. S. N., assistant.	Soundings inside of Matagorda bay, Tex., extended from the entrance northward and eastward to Palacios Point, and carried westward to Indianola and Well Point.
SECTION X.				
Western coast of the U. States, from the San Diego boundary to the forty-second parallel, including the coast of California.	1	Triangulation	W. E. Greenwell, assistant	Primary work completed between San Pedro and Santa Barbara, on the coast of Santa Barbara channel. Preliminary bases measured and triangulations made on Santa Rosa and San Clemente islands.
	2	Triangulation and astronomical, and magnetic observations.	George Davidson, assistant; E. H. Fauntleroy and A. T. Mosman, aids, (part of season;) Jas. Gilliss and Horace Anderson, aids, (part of season.)	Primary triangulation of the coast of California extended from Bodega Head, northward, to Russian river, with secondary and tertiary triangulation to include Bodega bay and the coast adjacent. Observations for latitude, longitude, azimuth, and the magnetic elements.
	3	Topography	W. M. Johnson, sub-assistant; C. M. Bache, sub-assistant, (part of season.)	Plane-table survey of Santa Cruz island continued, and topography commenced on the shores of Half Moon bay, Cal.
	4	Topography	A. F. Rodgers, assistant; C. M. Bache, sub-assistant, (part of season;) David Kerr, aid.	Coast topography between Duxbury reef and Point Reyes, Cal., completing the survey of the shores of Drake's bay; also plane-table survey of the shores of Petaluma creek, (San Pablo bay,) from its entrance upwards to, and including, the town of Petaluma and Lakeville.
	5	Hydrography	Commander James Alden, U. S. N., assistant.	Soundings completed at the mouth of Salinas river, (Monterey bay, Cal.,) on Oakland bar, (resurvey,) with current observations; and at Tongue shoal and Hog's Back, Sacramento river. Petaluma creek, (San Pablo bay,) sounded out to Petaluma, and coast hydrography extended from Duxbury reef, northward, and above Point Reyes, including Drake's bay and lagoon, and Tomales bay.
	--------	Tidal observations	Lieut. G. H. Elliott, U. S. engineers.	Series kept up with self-registering gauges at San Diego and San Francisco. (See also Section XI.)
SECTION XI.				
Western coast of the U. States, from the forty-second parallel to the northwestern boundary, includ'g the coast of Oregon and that of Washington Territory.	1	Triangulation and topography.	James S. Lawson, sub-assistant; A. T. Mosman, aid.	Preliminary base measured at Gray's harbor, W. T., and triangulation completed from the entrance to the mouth of Chehalis river; work continued in the Gulf of Georgia, including measurement of the preliminary base on Sandy Point, and topography commenced on San Juan island, Washington sound.

APPENDIX No. 1—Continued.

Limits of sections.	Parties.	Operations.	Persons conducting operations.	Localities of operations.
SECTION XI—(Continued)	....	Astronomical observations.	Lieut. J. M. Gilliss, U. S. N.; A. T. Mosman and James Gilliss, aids.	Solar eclipse observed at Muck prairie, near Fort Steilacoom, W. T., for longitude purposes.
	....	Tidal observations	Lieut. G. H. Elliott, U. S. engineers.	Regular observations continued with self-registering gauge, at Astoria. (See also Section X.)

APPENDIX No. 2.

List of Army Officers on Coast Survey duty March 1, 1860.

Officers.	Rank.	Date of attachment.
Thomas J. Cram	Captain topographical engineers	March 26, 1858.
W. R. Palmer	......do............do	November 17, 1857.
M. L. Smith	......do............do	December 9, 1856.
E. B. Hunt	Captain engineers	May 5, 1851.
A. P. Hill	First lieutenant 1st artillery	November 23, 1855.
George Bell	......do............do	November 15, 1859.
R. G. Cole	First lieutenant 8th infantry	June 11, 1859.
W. R. Terrill	First lieutenant 4th artillery	March 19, 1858.
J. R. Smead	First lieutenant 2d artillery	May 21, 1859.
Thomas Wilson	First lieutenant 5th infantry	May 26, 1857.
O. D. Greene	Second lieutenant 2d artillery	November 23, 1859.

APPENDIX No. 3.

List of Army Officers on Coast Survey duty September 1, 1860.

Officers.	Rank.	Date of attachment.
Thomas J. Cram	Captain topographical engineers	March 26, 1858.
W. R. Palmer	......do............do	November 17, 1857.
M. L. Smith	......do............do	December 9, 1856.
E. B. Hunt	Captain engineers	May 5, 1851.
W. G. Gill	First lieutenant 4th artillery	June 16, 1860.
A. P. Hill	First lieutenant 1st artillery	November 23, 1855.
N. H. McLean	First lieutenant 2d infantry	March 21, 1860.
George Bell	First lieutenant 1st artillery	November 15, 1859.
R. G. Cole	First lieutenant 8th infantry	June 11, 1859.
W. R. Terrill	First lieutenant 4th artillery	March 19, 1858.
J. R. Smead	First lieutenant 2d artillery	May 21, 1859.
Thomas Wilson	First lieutenant 5th infantry	May 26, 1857.
W. Craig	First lieutenant 8th infantry	March 9, 1860.
O. D. Greene	Second lieutenant 2d artillery	November 23, 1859.

APPENDIX No. 4.

List of Navy Officers on Coast Survey duty March 1, 1860.

Vessels.	Locality of service.	Officers.	Rank.	Date of attachment.
	Office-work	S. S. Lee	Commander	August 8, 1859.
	Do	W. T. Muse	do	February 27, 1857.
	Do	Silas Bent	Lieutenant	March 1, 1860.
Steamer Bibb	Under orders for Section VI.	Alexander Murray	Lieutenant commanding	April 23, 1858.
Schooner Crawford	Section V	J. P. Bankhead	do	October 16, 1858.
Schooner Varina	Section V	C. M. Fauntleroy	do	November 13, 1858.
Schooner Arago	Section VI	Wm. Ronckendorff	do	November 10, 1859.
Steamer Corwin	Section VI	John Wilkinson	do	June 25, 1859.
Steamer Vixen	Section VII	T. S. Phelps	do	August 23, 1859.
Steamer Walker	Section VIII	J. J. Guthrie	do	October 10, 1859.
Steamer Active	Sections X and XI	James Alden	Commander	May 18, 1849.
		J. G. Mitchell	Lieutenant	June 14, 1858.
		James Suddards	Passed assistant surgeon	July 1, 1857.

APPENDIX No. 5.

List of Navy Officers on Coast Survey duty September 1, 1860.

Vessels.	Locality of service.	Officers.	Rank.	Date of attachment.
	Office-work	S. S. Lee	Commander	August 8, 1859.
	Do	Silas Bent	Lieutenant	March 1, 1860.
	Do	J. J. Guthrie	do	October 10, 1859.
Steamer Bibb	Repairing at New York	A. Murray	Lieutenant commanding	April 23, 1858.
Steamer Vixen	Section I	T. S. Phelps	do	August 23, 1859.
Steamer Corwin	Section I	J. Wilkinson	do	June 25, 1859.
Schooner Crawford	Section I	J. P. Bankhead	do	October 16, 1858.
Schooner Varina	Section II	C. M. Fauntleroy	do	November 13, 1858.
Steamer Hetzel	Section III	W. T. Muse	Commander	February 27, 1857.
Schooner Arago	Section IX	W. Ronckendorff	Lieutenant commanding	November 10, 1859.
Steamer Active	Sections X and XI	James Alden	Commander	May 18, 1849.

APPENDIX No. 6.

Information furnished from the Coast Survey office by authority of the Treasury Department in reply to special calls during the year 1859–'60.

Date.		Names.	Data furnished.
1859.			
Oct.	8	A. W. Shaffer, esq	Bearings from stations on Hudson river, near Catskill, N. Y.
	15	Captain T. J. Lee	Variation of the magnetic needle at Snead station, Va.
	26	Professor A. Guyot, Princeton, N. J	Geodetic elements of the earth.
Nov.	11	J. A. Milliken and L. H. Eaton	Geographical positions near Cherryfield and Bangor, Me.
	11	T. B. Brooks, Monroe, N. Y	Magnetic elements at stations on the Atlantic coast.
	17	G. W. Blunt, esq , New York	Hydrography of Atchafalaya bay, La.
	21	do	Hydrography of coast of North Carolina.
Dec.	3	Hon. I. I. Stevens	Tracing from hydrographic sheet of Canal de Haro, &c., W. T.
	5	G. W. Blunt, esq., New York	Additional hydrography of Atchafalaya bay, La.
	20	George Harding, esq., Philadelphia	Shore-line measurements.
	21	Hon. Alexander Evans	Distances near Frenchtown and Elk Landing, Md.
	22	Hon. Jedediah Jewett, mayor of Portland, Me	Tracing from the survey of Portland harbor, Me.
	31	Lieutenant John Mullan, U. S. A	Computed predictions of moon culminations.
1860.			
Jan.	5	J. H. Kroehl, New York	Hydrography of the vicinity of Diamond reef, New York harbor.
	6	Edgar Burroughs, esq	Topography of Back bay, Va.
	12	B. Callan, esq	Geodetic elements of the earth.
	13	John Downes, esq	Height of Agamenticus station, N. H.
	16	Hon. D. L. Yulee	Sea route distances along the Atlantic and Gulf coast.
	17	James Anderson, esq., Rockville, Md	Magnetic variation near Washington, D. C.
	19	Captain D. Leadbetter, Mobile	Hydrography of Mobile bay, La.
	24	G. L. Richardson, esq	Elements for projecting maps.
	25	W. H. Mailler, New York	Hydrography of Coenties's reef, New York harbor.
	29	Hon. D. L. Yulee	Distances between ports on the Atlantic and Gulf of Mexico.
	30	G. S. Quackenbos, New York	Variation of the magnetic needle near Washington, D. C.
Feb.	4	T. Doane, esq	Descriptions of stations in Boston harbor.
	8	G. L. Richardson, New York	Tracing from the survey of Boston harbor.
	9	Captain J. H. Simpson, U. S. A	Meteorological observations at San Francisco.
	16	G. W. Blunt, esq , New York	Hydrography of the Hudson and East rivers, N. Y.
	16	W. G. Bogart, esq	Maximum width of Hudson river, N. Y.
	28	Henry Toland, esq	Tracing from survey of the vicinity of Pensacola, Fla.
March	2	H. B. Dawson, esq	Hydrography of Lake Borgne, La.
	9	Hon. J. C. Burch	Tracing from the hydrographic sheet of Crescent City harbor, Cal.
	19	John Trautwine, esq	Geodetic elements of the earth.
	26	W. Gill, esq., Richmond, Va	Topography of the city of Richmond, Va.
April	6	M. Semple, esq., Philadelphia	Magnetic variation in lat. 38° N., long 79° W.
	9	Hon. D. L. Yulee	Sea route distances between ports on the Gulf of Mexico.
	19	E. M. Stanton, esq., Washington, D. C	Tracing from survey of the vicinity of Oakland, Cal.
	20	John Downes, esq	Latitude of Webb's station, Md.
	21	A. M. Lea, esq	Material for map of the vicinity of Aransas, Tex.
	30	Captain D. Leadbetter, Mobile	Hydrography of Mobile bay.
May	9	General Duff Greene	Soundings in the Rigolets, La.
	12	Commander T. T. Hunter, U. S. N	Hydrography of the entrance and bar of St. Augustine harbor.
	30	C. C. Walden, esq	Depths on sections across the Florida straits.
June	2	A. M. Lea, esq	Distances and azimuth between Aransas light and Mazatlan.
	4	A. S. Easton, esq	Topography of the western shore of San Francisco bay, Cal.
	9	Light-house Board	Tracing from the hydrographic sheet of Newark bay, N. J.
	11	F. L. Olmstead	Hydrography of East river, Harlem river, and Spuyten Duyvel creek, N. Y.
	14	James Blair, esq	Hydrography of Brunswick harbor, Ga.
	23	Marshall Parks, esq., Norfolk	Soundings in the North river, Va.
July	12	G. W. Blunt, esq., New York	Lines of soundings from Charleston to Fernandina, Fla.
	20	do	Off-shore hydrography from Cape Henry to Carysfort reef, Fla.
	27	Captain E. B. Hunt, corps of engineers	Hydrography of Key West harbor and approaches.
	27	Hon. D. L. Yulee	Tracing from hydrographic sheet of Cedar Keys, Fla.
Aug.	7	Joseph C. Chaires, esq., Tallahassee, Fla	Local features of St. George's sound, Fla.
	8	Hon. D. L. Yulee	Sea route distances Gulf of Mexico and Pacific ocean.
Sept.	19	City of Portland, Me	Topography of Portland harbor, Cape Elizabeth, &c.
	19	W. A. Thornton, esq., Eufaula, Ala	Notes of meridian-line determination at Eufaula.

APPENDIX No. 7.

Statistics of field and office-work of the United States Coast Survey during the years—

	Previous to 1844.	1844.	1845.	1846.	1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	Total.
Reconnaissance—																		
Area, in square miles	9,642	1,140	3,739	1,830	2,950	3,940	10,159	3,280	3,510	1,706	1,708	795	1,487	4,072	2,855	709	1,782	55,304
Parties, number of, in each year	4	2	4	5	5	7	6	4	6	6	5	13	7	5	8	4	3	....
Base lines—																		
Primary, number of	1	2	....	....	1	1	....	1	....	....	1	....	2	....	1	....	....	10
Secondary, number of	2	....	....	....	2	1	4	3	3	4	5	2	6	8	1	4	5	52
Length of, in miles	19½	16	....	....	9¼	13	6¼	17½	2	4½	18½	3¾	24½	9½	9	3½	6¼	163
Triangulation—																		
Area, in square miles	9,076	795	2,166	1,185	1,903	2,592	4,091	2,097	2,465	1,703	3,089	2,701	2,729	2,793	1,640	3,033	3,724	47,782
Extent of general coast, in miles	570	179	162	123	159	115	285	216	243	220	94	246	188	320	357	278	358	4,113
Extent of shore-line, in miles, including bays, sounds, islands, and rivers	1,588	589	554	1,018	541	796	1,328	730	1,097	1,104	884	1,269	1,401	1,895	1,481	1,715	2,092	20,082
Horizontal angle stations occupied	750	120	80	197	120	98	204	157	184	223	224	204	410	544	385	384	344	4,628
Geographical positions determined	1,183	147	148	372	194	227	319	294	307	446	346	388	584	1,240	777	603	794	8,369
Vertical angle stations occupied	15	2	5	7	3	1	18	13	22	14	7	89	6	1	4	11	17	235
Elevations determined, number of	44	12	7	46	44	1	59	22	53	66	9	127	6	12	15	14	31	568
Parties, number of, in each year	4	5	8	7	8	10	13	14	14	13	18	17	17	20	20	19	21	....
Astronomical operations—																		
Stations occupied for azimuth	9	8	2	2	3	3	4	4	6	6	9	5	4	2	1	2	7	77
Stations occupied for latitude	9	8	5	3	8	2	4	6	8	17	20	6	4	6	3	5	5	119
Stations occupied for longitude	1	1	....	2	3	3	7	3	7	18	21	4	1	1	2	2	....	76
Permanent longitude stations	....	1	1	2	1	1	2	3	5	5	5	4	3	1	1	1	1	....
Special longitude stations for occultations, &c	....	....	....	....	....	....	....	....	....	....	....	....	....	....	23	30	24	....
Parties, number of, in each year	1	3	2	2	3	3	5	5	6	4	7	7	6	4	3	4	5	....
Magnetic stations occupied, number of	....	14	21	28	19	4	11	9	10	8	13	9	8	23	4	5	18	204
Parties, number of, in each year	....	2	3	3	3	3	5	4	3	2	3	6	3	4	3	3	4	....
Topography—																		
Area surveyed, square miles	6,131	195	503	750	595	471	532	652	681	653	554	513	656	536	1,003	706	476	15,607
Length of general coast, in miles	414	110	168	119	117	185	95	133	260	236	251	174	176	165	309	172	163	3,247
Length of shore-line, in miles, including rivers, creeks, and ponds	7,667	424	879	1,120	1,460	1,703	1,709	1,557	1,760	1,737	2,100	1,796	2,138	2,398	3,913	3,408	2,334	38,103
Length of roads, in miles	11,734	395	997	1,402	1,354	640	504	511	500	732	502	618	733	750	1,404	870	431	24,077
Parties, number of, in each year	6	5	6	8	9	9	11	11	13	13	17	12	17	17	23	23	22	....
Hydrography—																		
Parties, number of, in each year	2	5	5	6	6	8	11	11	12	9	9	10	11	12	12	10	9	....
Number of miles run while sounding	29,214	1,857	3,493	3,559	3,138	8,047	4,299	5,995	10,590	9,534	9,050	9,141	13,115	15,305	12,377	8,884	9,103	156,701
Area sounded out, square miles	9,601	663	677	574	979	2,185	1,335	2,012	3,200	2,823	2,061	1,937	3,433	3,743	2,705	1,799	4,300	43,997
Miles run additional, of outside or deep-sea soundings	1,800	1,020	....	....	210	2,240	....	1,198	2,037	360	1,902	2,793	5,219	1,202	3,218	2,092	2,353	27,644
Soundings, number of	808,147	120,827	125,173	220,402	228,402	255,003	265,824	264,718	371,660	288,375	305,377	162,454	526,875	439,614	506,034	513,607	398,053	5,800,545
Soundings in Gulf Stream for temperature	....	....	118	581	207	425	....	....	....	....	1,053	257	310	....	478	172	114	3,715
Tidal stations, permanent	....	2	2	2		3	3	3	4	4	7	7	7	8	8	10	10	....

APPENDIX No. 7—Continued.

	Previous to 1844.	1844.	1845.	1846.	1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	Total.
Hydrography—																		
Tidal stations occupied temporarily	127	14	33	39	33	29	35	41	51	76	78	89	80	77	74	50	26	952
Tidal parties, number of, in each year	2	5	5	5	5	8	11	11	12	9	11	12	13	14	14	13	10	....
Current stations occupied	....	27	42	41	59	54	28	44	41	24	89	10	84	84	156	47	38	868
Current parties, number of, in each year	....	3	5	3	3	4	6	4	7	7	5	3	5	6	6	2	2	....
Specimens of bottom, number of	1,029	2,776	89	129	371	769	287	381	278	215	141	135	255	146	422	668	164	8,255
Records—																		
Triangulation, originals, number of volumes	97	12	17	23	17	32	38	40	33	33	64	46	79	96	76	96	94	893
Astronomical observations, originals, number of vols.	17	10	11	10	16	22	72	30	41	48	29	88	35	12	35	63	27	566
Magnetical observations, originals, number of vols.	4	2	1	6	7	4	3	5	5	7	6	4	33	13	4	10	9	123
Duplicates of the above, number of volumes	27	26	32	32	44	49	19	23	45	73	76	84	139	101	140	168	77	1,155
Computations, number of volumes	78	25	17	21	26	23	57	24	40	72	101	91	109	99	83	101	88	1,055
Hydrographic soundings and angles, originals, vols.	188	22	26	152	54	154	134	170	213	206	183	66	332	197	319	322	306	3,044
Hydrographic soundings and angles, duplicates, vols.	28	2	5	4	11	11	12	12	16	27	15	7	26	27	21	20	19	263
Tidal and current observations, originals, vols	127	23	47	51	44	40	67	88	114	139	123	70	196	110	213	104	75	1,631
Tidal and current observations, duplicates, vols	....	23	47	51	44	41	63	79	385	132	114	79	87	100	67	74	57	1,443
Sheets from self-registering tide-gauges, number of	....	....	....	....	....	....	....	....	....	26	72	106	80	103	119	141	149	796
Tidal reductions, number of volumes	....	46	94	102	88	80	16	58	22	26	17	99	79	73	63	64	52	979
Total number of volumes of records	566	191	297	452	351	456	481	529	914	763	728	634	1,115	828	1,021	1,022	804	11,152
Maps and charts—																		
Topographical maps, originals	168	14	16	25	29	20	22	30	41	47	54	45	55	51	74	44	36	771
Hydrographic charts, originals	142	9	8	18	18	21	16	20	47	56	56	52	65	62	51	33	37	711
Reductions from original sheets, number of	15	9	15	16	17	13	18	22	26	48	35	27	36	39	40	35	92	503
Total number of manuscript maps and charts	325	32	39	59	64	54	56	72	114	151	145	124	156	152	165	112	165	1,985
Number of sketches made in field and office	311	24	33	32	29	48	82	85	126	137	103	101	132	125	132	127	353	1,980
Engraving and printing—																		
Engraved plates of finished charts, number of	5	2	3	5	3	6	3	5	6	5	4	2	7	3	7	6	8	80
Engraved plates of preliminary charts, sketches and diagrams for the Coast Survey reports, number of	....	....	....	4	5	7	6	10	38	20	39	42	46	51	51	25	21	365
Electrotype plates made in each year	....	....	....	....	1	7	6	25	16	23	47	77	50	69	79	95	87	582
Finished charts published in each year	....	4	3	4	3	10	3	4	6	6	3	2	8	3	5	6	6	76
Preliminary charts and hydrographic sketches published	....	....	....	2	4	2	4	10	36	19	34	34	34	38	41	22	15	295
Printed sheets of maps and charts distributed	....	169	416	1,708	1,104	2,923	1,848	326	5,649	5,799	8,042	5,195	5,392	8,858	19,147	4,209	10,486	81,271
Printed sheets of ditto deposited with sale agents	....	....	880	1,686	4,981	5,016	1,506	3,115	5,168	6,866	4,375	3,232	2,577	2,895	648	1,717	3,584	48,249
Library—Number of volumes	....	....	....	....	....	655	95	590	333	171	273	155	250	389	106	116	174	3,307
Instruments—Cost of	....	....	....	....	....	....	$8,326	$4,652	$4,603	$3,835	$5,296	$5,402	$3,958	$5,369	$3,185	$1,224	$1,852	....

GENERAL NOTE.

Parties.—An average number is given for the years previous to 1844. A party operating in more than one section during the year is counted but once.

Triangulation.—The extent of general coast is measured in general outline, including Delaware and Chesapeake, as well as all open bays, but omitting the minor indentations of the sea-coast. The extent of shore-line is also measured in general outline, and includes such rivers only as have been triangulated.

Topography.—The length of general coast is measured similarly to that under triangulation; but the shore-line under topography represents the whole water-line surveyed, including all the minor indentations, as represented on the plane-table sheets.

Records.—The total number of volumes of records given in the table is greater than the number now on hand, owing to the binding up of separate volumes.

Engraved plates.—Progress sketches (averaging fourteen yearly) are not counted.

Library.—The number of volumes purchased and donated up to 1849 was 655.

It is to be remarked that the numbers appearing in the column of this table for the year immediately preceding that of its compilation are, in some cases, subject to be changed, more or less, in the succeeding report, owing to data not being, at the time of compilation, fully turned into the office from the distant parties in the field.

APPENDIX No. 8.

General list of Coast Survey discoveries and developments to 1859, *inclusive.*

1. Only eighteen feet at mean low water found on the rock one mile to the southward of Seguin island, coast of Maine, 1859.

2. Temple's ledge, near Cape Small Point, Me., 1857.

3. True position of the Hussey rock, in Casco bay, determined, correcting the erroneous one assigned on previous charts, 1859.

4. Determination of the position of a sunken rock on which the steamer Daniel Webster struck, in Casco bay, on the evening of the 13th of October, 1856.

5. Determination of the dimensions of Alden's rock, near Cape Elizabeth, Me., 1854.

6. Determination of the position of the "Hue and Cry," the "Old Proprietor," and other dangers off Cape Elizabeth, Me., 1859.

7. Huzzey's rock, south of Fletcher's Neck, Me., determined in position, 1859.

8. Development of a four-fathom bank off Cape Porpoise, Me., 1859.

9. Fishing ledge, off Kennebunk, Me., thoroughly sounded, 1858.

10. A rock one mile to the southward and westward of Boon island, with seventeen feet water. The sea breaks on it in heavy weather, 1858.

11. Development of a rock off Ogunquit, bare at low tides, and very little known, 1859.

12. Development of Boon Island ledge, coast of Maine, 1858.

13. A rock off Cape Neddick, Maine, determined in position, 1858.

14. A detached rock two-thirds of a mile northward and eastward of York ledge, Me., 1858.

15. Determination of the position of a rock more than a mile off the mouth of York river, Me.; bare at low tides and dangerous to coasters, 1858.

16. Development of Duck Island ledge, 1858.

17. A fishing bank sounded out off Wood island, coast of Maine, 1859.

18. A very dangerous rock, with only six and a half feet water, off the entrance to Portsmouth harbor, N. H., about four nautical miles eastward from the Whale's Back light, 1858.

19. A rock with twelve feet at mean low water, about four miles and a third eastward of the Whale's Back, 1858.

20. Determination of rocks off Marblehead and Nahant, 1855.

21. A rock (not on any chart) in the inner harbor of Gloucester, Mass., discovered in 1853.

22. A bank ninety miles eastward of Boston, with about thirty-six fathoms of water, probably a knoll connected with Cashe's ledge, but with deep water between it and the ledge, 1853.

23. Boston harbor; Broad Sound channel thoroughly surveyed and marks recommended, 1848.

24. Several rocks in the fair channel-way in Boston harbor entrance, 1854.

25. An extension of the sand-spit to the southward of Sunken ledge, Boston harbor, since the survey of 1847, 1858.

26. A bank (Stellwagen's bank) with ten and a half to fourteen and a half fathoms of water on it, at the entrance to Massachusetts bay, and serving as an important mark for approaching Boston and other harbors, 1854.

27. Extension of Stellwagen's bank to the southward and eastward some sixteen or seventeen square miles, enclosed by the twenty-fathom curve, 1855.

28. Changes in the vicinity of East harbor, (Cape Cod,) 1857.

29. A dangerous sunken ledge (Davis's ledge) to the eastward and in the neighborhood of Minot's ledge, 1854.

30. Development of a reef extending between Minot's and Scituate light, 1856.

31. A sunken rock, with only six feet on it at low water, off Webster's Flag-Staff, Massachusetts bay, 1856.

32. A dangerous rock near Saquish Head, entrance to Plymouth harbor, 1856.

33. Three rocks determined in position, partly bare at low water, off Manomet Point, Massachusetts bay, 1856.

34. Determination of a very dangerous rock off Indian hill, and four miles southward of Manomet Point, Massachusetts bay, with as little as six feet water on it, 1856.

35. Determination of the position of a small rock with less than four feet at mean low water, near the channel and in the vicinity of Great rock, Hyannis harbor, Massachusetts, 1859.

36. Probable connection of George's bank and the deep-sea banks north and east of Nantucket, 1855.

37. The decrease of depth, with general permanence of form of George's bank, off the coast of Massachusetts, 1857.

38. A shoal spot near Little George's bank, 1857.

39. Non-existence determined of "Clark's bank" and "Crab ledge," laid down on certain charts as distinct from an immense shoal ground off Cape Cod peninsula, 1856.

40. Nantucket shoals; Davis's New South shoals, six miles south of the old Nantucket South shoals, in the track of all vessels going between New York and Europe, or running along the coast from the eastern to the southern States, or to South America; discovered in 1846.

41. Two new shoals north and east of Nantucket; discovered in 1847.

42. Six new shoals near Nantucket; the outermost fourteen and a half miles from land, and with only ten feet water; discovered in 1848.

43. McBlair's shoals, off Nantucket; discovered in 1849.

44. The tidal currents of Nantucket shoals and the approaches, 1854.

45. Davis's bank, Nantucket shoals; discovered in 1848, and survey finished in 1851.

46. Fishing Rip, a large shoal extending north and south, about ten miles to the eastward of Davis's bank, and thirty miles from Nantucket, with four and a half fathoms; surveyed in 1852.

47. A ridge connecting Davis's New South shoal and Davis's bank; found in 1853.

48. A small bank or knoll with but five fathoms on it, about five miles east of Great Rip, with twelve fathoms between it and Davis's bank and Fishing Rip, the water gradually deepening outside of it to the northward and eastward beyond the limits of the series of shoals, 1853.

49. Discovery of Edwards's shoal, one mile and seven-eighths southward of Nantucket light-boat, 1855.

50. Examination of the interference tides of Nantucket and Martha's Vineyard sounds, 1855.

51. The study of the tidal currents of the Vineyard and Nantucket sounds, 1857.

52. Contraction of the inlet at the north end of Monomoy island, and opening of a new entrance to Chatham harbor, 1853.

53. Muskeget channel; surveyed by Lieut. C. H. Davis in 1848, and Lieut. C. H. McBlair in 1850.

54. Discovery of two shoal spots, with twelve and thirteen feet water, eastward from Great and Little Round shoals, Nantucket sound, 1856.

55. Determination of two shoal spots near the northern extremity of Davis's bank, with fourteen and eighteen feet water, 1856.

56. Further development of Edwards's shoal, three-fourths of a mile from the Southern Cross Rip, Nantucket sound, 1856.

57. Shoal sand ridges discovered northward of Great Point light, Nantucket sound, 1856.

58. Important changes in geographical feature at the southeastern end of Martha's Vineyard, Muskeget channel, 1856.

59. Numerous rocks in Martha's Vineyard sound, Long Island sound, and the various bays and harbors connected with them.

60. Luddington rocks determined in position, about ten yards apart, a mile and a half (nautical) southwest, by compass, from New Haven light, 1858.

61. The tidal currents of Long Island sound, 1854.

62. The tidal currents of Hell Gate, 1857.

63. Least water on the Hell Gate rocks, determined by dragging, 1857.

64. Tidal currents in East river, N. Y., and surface and sub-currents investigated in New York harbor, the lower bay, and on the bar, 1858.

65. The currents of the great bay between Massachusetts, Rhode Island, Connecticut, New York, and New Jersey, 1855.

66. Gedney's channel into New York bay, having two feet more water than the old channels. Had the true depth of this channel been known in 1778, (then probably existing, as seen by comparing old and new charts,) the French fleet under Count D'Estaing would have passed into the bay, and taken the assembled British vessels, 1845.

67. The changes in New York harbor, near New York city, between 1845 and 1858.

68. Increase of depth in Buttermilk channel, ascertained and made known in 1848 by survey of Lieut. D. D. Porter, U. S. N.

69. The existence of a seventeen-foot spot on the shoal off the battery, New York harbor; the extension of the shoal towards the channel, and the shoaling of the water generally between the shoal and shore, 1859.

70. Shoal in the main ship channel of New York harbor, 1855.

71. The existence and character of sub currents ascertained as bearing on the physical conditions of New York harbor, 1859.

72. The tides of Hudson river, 1856.

73. Sandy Hook; its remarkable increase traced from the surveys of the topographical engineers and others, and by several successive special surveys made between 1844 and 1857.

74. Delaware bay; Blake's channel at the entrance, discovered in 1844; open when the eastern channel is closed by ice. This discovery has served to develop strikingly the resources of that portion of Delaware.

75. Blunt's channel, in Delaware bay.

76. Changes in the Delaware near the Pea Patch, 1847.

77. The true extent and position of the dangerous shoals near Chincoteague inlet, Va., 1852.

78. Metomkin inlet, Va., shoaling from eleven to eight feet in the channel during 1852.

79. Two channels into Wachapreague inlet, Va., one from the northward and the other from the eastward, both with seven feet water at low tide, 1852.

80. A shoal half a mile in extent not put down on any chart, five and a half miles east from the north end of Paramore's island, Va. It has but four fathoms water on it, and nine fathoms around it, 1852.

81. Great Machipongo inlet, Va. Found to have a fine wide channel, with eleven feet water on the bar at low ebb, and fourteen at high tide. Good anchorage inside in from two to eight fathoms. The best harbor between the Chesapeake and Delaware entrances, 1852.

82. Two shoals near the entrance to the Chesapeake, one four and three quarter nautical miles SE. by E. from Smith's island light-house, with seventeen feet water upon it, the other E. by S. nearly seven and three quarter miles from the same light, with nineteen and a half feet upon it, 1853.

83. Only three feet water upon the "Inner Middle," the shoal part of the Middle Ground, west of the "north channel," at the Chesapeake entrance, 1852.

84. A twenty-five fathom hole two and a half miles W.SW. from Tazewell triangulation

point, eastern shore of the Chesapeake; all other charts give not more than sixteen fathoms in this vicinity.

85. A shoal at the mouth of the Great and Little Choptank, in Chesapeake bay, 1848.

86. The sounding and measurement of the bars in Rappahannock river, 1855.

87. The general permanence of the Bodkin channel and shoals in its vicinity, at the entrance of the Patapsco river, between 1844 and 1854.

88. Changes developed in the shore-lines at the entrance of Little Annemessex river, Chesapeake bay, 1859.

89. A shoal (New Point shoal) in Chesapeake bay, with sixteen feet water on it, southeast from New Point Comfort light-house, off Mobjack bay, 1854.

90. Re-examination of York spit, Chesapeake bay, and least water determined, (nine feet,) 1855.

91. York river, Va., as a harbor, 1857.

92. A reconnaissance of the Wimble shoals, near Nag's head, coast of N. C., 1854.

93. Submarine range of hills beyond the Gulf Stream tracked from Cape Florida to Cape Lookout, 1855.

94. Deep water found on Diamond shoal, and a dangerous nine-feet shoal off Cape Hatteras, 1850.

95. A new channel, with fourteen feet water, into Hatteras inlet, formed during the year 1852, which is better and straighter than the old channel.

96. Changes at Hatteras and Ocracoke inlets, 1857.

97. The general permanence in depth on the bar of Beaufort, N. C., with the change of position of the channel, 1854.

98. Changes on the bar of Beaufort, N. C., 1857.

99. The well-ascertained influence of prevailing winds in the movement of the bars at Cape Fear and New Inlet entrances, and the gradual shoaling of the main bar; the latter fact being of great importance to the extensive commerce seeking that harbor, 1853.

100. Changes in the main Western and New Inlet channels in Cape Fear, 1855.

101. Frying Pan shoals, off Cape Fear, N. C.; a channel of two and a half fathoms, upwards of a mile wide, distant eleven nautical miles from Bald Head light-house across the Frying Pan shoals. A channel, extending from three to four miles from the point of Cape Fear, to eight or eight and a half miles from it, with sufficient water at low tide to allow vessels drawing from nine to ten feet to cross safely. A channel at the distance of fourteen nautical miles from Bald Head light-house, one mile wide, with three and a half to seven fathoms water on it. The Frying Pan shoals extend twenty nautical miles from Bald Head light-house, and sixteen, seventeen, and eighteen feet water is found seventeen and eighteen nautical miles out from the light, 1851.

102. Shoaling of Cape Fear River bar thoroughly examined for purposes of improvement, 1852.

103. Changes of shore-line and hydrography determined at the Cape Fear entrances, N. C., 1858.

104. Changes of the Cape Fear bars and channels, 1857.

105. Changes at the entrance of Winyah bay and Georgetown harbor, and the washing away of Light-house Point at the same entrance, 1853.

106. Less water found off Cape Romain by preliminary examination than has been heretofore assigned, 1859.

107. Maffitt's new channel, Charleston harbor, with the same depth of water as the ship channel, 1850.

108. The changes in Maffitt's channel, Charleston harbor, S. C., from 1852 to 1857.

109. Increase of depth developed in Maffitt's channel, Charleston harbor, S. C., 1858.

110. Changes in the main ship channel, Charleston harbor, 1855.

111. Changes in the channels at the entrance of Charleston harbor, 1852.

112. The remarkable discovery of continuous deep-sea soundings off Charleston, and of soundings in the depth of between four and five hundred fathoms beyond the Gulf Stream, 1853.

113. Development of the changes affecting the entrance to North Edisto river, S. C., 1856.

114. Discovery of a new channel between Martin's Industry (shoal) and the southeast breakers, Port Royal entrance, S. C., 1856.

115. Discovery of cold water at the bottom of the ocean below the Gulf Stream, along the coasts of North and South Carolina, Georgia, and Florida, 1853.

116. The discovery of the cold wall, alternate warm and cold bands, and various other features of the Gulf Stream, especially such as concern its surface and deep-sea temperatures, and its distribution relative to the shore and bottom of the ocean.

117. Various facts relative to the distribution of minute shells on the ocean bottom, of probable use to navigators for recognizing their positions.

118. Examination of Doboy, St. Simon's, and Cumberland entrances, 1855.

119. A shoal inside of the entrance to Amelia river, Fla., 1857.

120. Hetzel shoal, off Cape Canaveral, Fla., 1850.

121. Temperature of 34° beneath the Gulf Stream, thirty-five miles east of Cape Florida, at a depth of three hundred and seventy fathoms, 1855.

122. Further explorations in developing the character of the Gulf Stream in the Florida channel, 1859.

123. A harbor of refuge (Turtle harbor) to the northward and westward of Carysfort light-house, Florida reef, with a depth of water of twenty-six feet at the entrance, 1854.

124. A new passage, with three fathoms water, across the Florida reef to Legaré harbor, under Triumph reef, (latitude 25° 30′ N., longitude 80° 03′ W.,) which, if properly buoyed, will be valuable as a harbor of refuge, 1852.

125. A safe rule for crossing the Florida reef near Indian key, 1854.

126. A new channel into Key West harbor, 1850.

127. Co-tidal lines for the Atlantic coast of the United States, 1854.

128. Rules for navigators in regard to the tidal currents of the coast, 1857.

129. Isaac shoal, near Rebecca shoal, Florida reef; not laid down on any chart, 1852.

130. Channel No. 4, a northwest entrance into Cedar Keys bay, 1852.

131. Directions for entering the harbor from Crystal River offing, western coast of Florida peninsula, 1856.

132. A new channel discovered, leading into St. George's sound, (Apalachicola, Fla.,) at the east end of Dog island, and anchorage connected with it, 1858.

133. Shoals near the east and west passes of St. George's sound, (Apalachicola, Fla.,) and a new channel found between St. George's and St. Vincent's islands, 1858.

134. Mobile Bay Entrance bar; in 1832 only seventeen feet at low water could be carried over it; in 1841 it had nineteen, and in 1847 it had twenty feet and three-quarters, as shown by successive surveys, 1847.

135. The diminution, almost closing, of the passage between Dauphine and Pelican islands, at the entrance of Mobile bay, 1853.

136. Horn Island channel, Mississippi sound, 1852.

137. The removal of the east spit of Petit Bois island in the hurricane of 1852, opening a new communication between the Gulf and Mississippi sound, and rendering Horn Island Pass more easy of access by the removal of knolls, 1853.

138. The accurate determination of Ship shoal, off the coast of Louisiana, in connection with the site for a light-house, 1853.

139. An increase of depth of water on the bar of Pass Fourchon, La., 1854.

140. Deep-sea soundings in the Gulf of Mexico, 1855–'56.

141. Tidal phenomena of the Gulf, 1855.

142. The changes at Aransas Pass, Texas, as bearing on the question of a light-house site, 1853.

143. Co-tidal lines of the Gulf of Mexico, 1856.

144. On the effect of wind in disturbing the tides of the Gulf of Mexico, 1856.

145. Development of a bar at the entrance of San Diego bay, Cal., 1856.

146. A shoal inside of Ballast Point, San Diego bay, with only twelve and a half feet water, not laid down on any chart, 1852.

147. The determination of the position and soundings on Cortez bank, off the coast of California, 1853.

148. Complete hydrographic survey and determination of a point of rock on Cortez shoal, 1856.

149. Tides of San Diego, San Francisco, and Astoria, 1854.

150. The non-existence of San Juan island, usually laid among the Santa Barbara group, 1852.

151. Co-tidal lines of the Pacific coast, 1855.

152. Determination of Uncle Sam rock, 1855.

153. Investigation of the currents of Santa Barbara channel, 1856.

154. Red sand marking the inner entrance to the Golden Gate, 1855.

155. Channel sounded out between Yerba Buena and the Contra Costa, San Francisco bay, 1855.

156. A reef developed off the Contra Costa flats, San Francisco bay, Cal., 1858.

157. Whiting's rock determined in position, near the "Brothers," at the entrance of San Pablo bay, Cal., 1858.

158. Further development of the extent of Commission rock, San Pablo bay, 1856.

159. Changes in the channel entrance of Humboldt bay or harbor, Cal., 1852 and 1853.

160. South channel, Columbia river, surveyed and made available to commerce, 1851. Changes of channels, their southward tendency, and a new three-fathom channel from Cape Disappointment due west to open water, Columbia entrance, 1852. Further changes, 1853.

161. The depth of water on the bars at the entrance of Rogue river and Umpquah river, Oregon, 1853.

162. A shoal at the northern entrance to the Strait of Rosario, W. T., giving good holding ground in thirty-three feet, 1854.

163. Boulder reef, northwest of Sinclair island, Rosario strait, partly bare at unusually low tides, and surrounded by kelp, 1854.

164. A bank of three and a half fathoms, about a mile off the southwest point of Sucia island, at the northern entrance of Washington sound, W. T., 1858.

165. Belle rock, in the middle of Rosario strait, visible only at extreme low tides, 1854.

166. Entrance rock, at the entrance of Rosario strait, 1854.

167. Unit rock, in the Canal de Haro, W. T., visible only at extreme low tides, 1854.

168. A three-fathom shoal in the Strait of Juan de Fuca, off the southeast part of Bellevue, or San Juan island, 1854.

169. Allen's bank, Admiralty inlet, W. T., 1857.

170. A five-fathom shoal in the Strait of Juan de Fuca, between Canal de Haro and Rosario strait, 1854.

171. A bank in eleven fathoms off the southern entrance to Canal de Haro, 1854.

172. The non-existence of two islands at the northern entrance of Canal de Haro, laid down on charts, 1853.

173. Various surveys and charts of small harbors on the Pacific coast of the United States,

and a continuous reconnaissance of the entire western coast and islands adjacent, a great part of which was imperfectly known.

174. Winds of the Western Coast of the United States, 1857.

Additional list for 1860.

1. A ledge with four fathoms water on it discovered S.SW. ¼ W. (true) and a mile and a quarter from Pemaquid light-house, coast of Maine.
2. Numerous dangerous reefs and ledges developed at the entrance and in the approaches of Damariscotta river, Me.
3. Two rocks, one with three and a quarter fathoms, the other with only ten feet of water, and a ledge with three and a half fathoms, found in the channel of Booth bay, Me.
4. Jeffrey's bank and Jeffrey's ledge, off the coast of Maine, thoroughly sounded out.
5. Determination of the position of White Rock ledge, at the entrance of Saugus river, Mass.
6. Discovery of a rock with only seventeen feet of water at mean low tide in the Narrows of Boston harbor.
7. Special investigation of the currents of Boston harbor.
8. Special tidal and current observations at the mouth of Scusset river, (Cape Cod bay.)
9. Discovery of a shoal lying N.NE., over six miles long, and twenty-four miles southeast of Davis's South shoal, with ten to ten and a half fathoms of water.
10. Extent of the sea encroachment at Cape Hatteras, and changes found near Hatteras inlet, N. C.
11. Greater depth found through the channel of Coosaw river, S. C., (inland passage,) than has been hitherto supposed to exist.
12. Changes in shore line and in depth observed in Ossabaw sound, Ga.
13. A new channel developed leading into Sapelo sound, Ga., three-quarters of a mile southward and better than the one in use.
14. A shoal spot found off the coast of Florida, ten miles from land and fifteen miles NE. of Indian River inlet.
15. Tennessee shoals, Florida reef, developed, giving only twelve feet of water on the outer shoal.
16. The position of a sunken wreck determined and marked, lying off Grassy key, Florida reef, and near the track of vessels.
17. Further investigation of the character of the Gulf Stream in the Florida straits.
18. Indications noticed of a deeper and better channel forming to lead to the East Pass anchorage, St. George's sound, Fla.
19. Changes in the depth of water observed by comparison of soundings at Perdido entrance.
20. The currents of Mobile bay specially investigated.

APPENDIX No. 9.

Letter to the Secretary of the Treasury, stating the position of a rock found off Pemaquid Point and of others in the channel of Booth bay, Me., determined by Lieut. Comg. T. S. Phelps, U. S. N., Assistant Coast Survey.

BOSTON, *November* 12, 1860.

SIR: I have the honor to communicate, in extracts from a report of Lieut. Comg. T. S. Phelps, U. S. N., Assistant Coast Survey, the particulars of several dangers to navigation, found while prosecuting the in-shore hydrography of the coast of Maine, in the vicinity of Muscongus bay, with the steamer Vixen.

"A small ledge, with four fathoms on it, was discovered a mile and a quarter S.SW. ¼ W. (true) from Pemaquid light-house; also two rocks and a ledge in Booth bay, with the following distances and bearings from Burnt Island light-house, viz:

"A rock with three and a quarter fathoms on it, six hundred yards south, (true.)

"A rock with only ten feet of water on it, eleven hundred and twenty-five yards S.SE., easterly, (true,) and three hundred and ninety yards from the nearest point of Squirrel island.

"A ledge with three and a half fathoms on it, and eight hundred and twenty yards distant, S. by E. ½ E., (true.)

"These rocks are in the channel way in beating into Booth bay, between Squirrel island and South Port ledge."

I would respectfully request authority to publish this communication in the form of a notice to mariners.

Very respectfully, yours,

A. D. BACHE,
Superintendent U. S. Coast Survey.

Hon. HOWELL COBB,
Secretary of the Treasury.

APPENDIX No. 10.

Report of Lieut. Comg. J. Wilkinson, U. S. N., Assistant Coast Survey, giving the bearings and ranges from the Corwin rock, in the Narrows of Boston harbor.

U. S. COAST SURVEY STEAMER CORWIN,
Boston Harbor, September 4, 1860.

SIR: I communicate herewith the bearings and ranges of the rock discovered in Boston Narrows during the recent examination made in that locality in pursuance of your instructions to me, dated July 14. This dangerous obstacle to navigation through the Narrows lies near mid-channel in four fathoms water, and has probably been encountered by vessels. Tower rock, (or ledge,) upon which many were supposed to have struck, is much nearer False Spit, and the sailing line passes between the two rocks, the distance between them being eighty-five yards.

Bearings from Corwin rock.

False Spit beacon, (E. ½ N.,) N. 74° 20′ E., true.
Narrows light-house, (NE. ¼ N.,) N. 33° E., true.
Nix's Mate beacon, (NW. ½ W.,) N. 61° W., true.

Ranges.

SW. corner of Nix's Mate beacon wall and foundry chimney in navy yard.
False Spit beacon and Boston light-house.

The newly discovered rock is of irregular shape, with a base of about a hundred and thirty feet in circumference and rises to a peak, with a depth on its crest of seventeen feet at mean low water, or fifteen feet and three-tenths at low water of spring tides. * * *

Very respectfully, your obedient servant,

J. WILKINSON,
Lieut. Comg., Assistant Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 11.

Letter to the Secretary of the Treasury, communicating particulars relative to the position and extent of the Asia Rip and Phelps's bank, off Nantucket, in extracts from the report of Lieut. Comg. T. S. Phelps, U. S. N., Assistant Coast Survey.

NEW YORK, *November* 14, 1860.

SIR: Information having been received from Messrs. E. & G. W. Blunt, of New York, that her Britannic Majesty's mail steamer Asia, Captain Lott, had, on the 16th of August last, passed through a tide rip to the southward and eastward of Nantucket, upon which a sounding of eleven fathoms was obtained, a surveying vessel, under the command of Lieut. Thomas S. Phelps, U. S. N., Assistant Coast Survey, was despatched to make an examination of the locality. This resulted in finding the shoal reported by Captain Lott, and also in the discovery of another of much greater extent.

I have the honor to communicate, for the general benefit of navigation, the following extracts from Lieut. Comg. Phelps's report:

"Near the position given by Captain Lott, of the Asia, is a small, well-defined rip, corresponding with his description, it being about a mile in length and a quarter of a mile in width, with eleven fathoms on the shoal. Half a mile to the eastward of this lies the south point of another shoal which extends to the N.NE., six and a half miles, with but ten and ten and a half fathoms of water upon it in several places.

"These shoals are distinctly marked by the rips on both the flood and ebb tides, but with deep and smooth water between them. Their position is between the—

$$\text{Latitudes}\left\{\begin{array}{l}40^\circ\ 46'\ \text{N.}\\ 40^\circ\ 53'\ \text{N.}\end{array}\right\}\qquad \text{Longitudes}\left\{\begin{array}{l}69^\circ\ 19'\ \text{W.}\\ 69^\circ\ 25'\ \text{W.}\end{array}\right\}$$

and about twenty three (23) miles SE. by E. from Davis's South Shoal light-vessel."

An examination was made of a number of other rips in the vicinity, but no shoals or banks were found except those above described.

I would respectfully request authority to publish the above.

Very respectfully, yours,

A. D. BACHE,
Superintendent U. S. Coast Survey.

Hon. HOWELL COBB,
Secretary of the Treasury.

APPENDIX No. 12.

Extracts from the report of Lieut. Comg. C. M. Fauntleroy, U. S. N., Assistant Coast Survey, relative to the bar and channels of Ossabaw sound, Ga.

UNITED STATES SURVEYING SCHOONER VARINA,
Ossabaw Sound, Ga., May 4, 1860.

DEAR SIR: The channel outside of Ossabaw sound is narrow, and the entrance leading in is nearly six miles to the southward of it. The entrance can be approached with confidence, as the soundings shoal gradually from eight to three and a quarter fathoms, and that depth can be carried in until the north point of Ossabaw island bears west, where the water deepens to six and seven fathoms. Thence on, the water shoals until within one mile and a half of the north point of Ossabaw, nearly abreast of the point of bare shoal, where the channel is sud-

denly obstructed by a belt extending inward for nearly two miles, over which but fourteen feet can be carried at low water, to deeper soundings and a safe anchorage off the west point of Raccoon island, close to, in six and seven fathoms, sticky bottom.

The line of shoal water extending from the north point of Ossabaw island to seaward, and to the southward for four miles, on the one hand, and a line of breakers (north breakers) extending from the point of Great Wassaw island eight miles to the southward, on the other, form this channel.

There is a slue or swash across the north breaker looking directly into the open way of the sound, through which at least ten feet may be carried. When buoyed out this passage will doubtless be much resorted to by coasting steamers and others, that now, for the most part, avoid the main entrance because of its distance and indirection.

There appears also to be a channel branching off from the main, in the vicinity of the first buoy, at the entrance looking toward Pine island, passing around the north side of Raccoon island, and leading into the Vernon and Little Ogeechee rivers; but until the soundings have been plotted it is quite impossible to form a correct idea of the depth or character of the water in the sound, as the bottom is very irregular and uneven. I shall therefore confine myself to the narration of such general features as have presented themselves during the progress of the survey. The soundings have been carried up the rivers as far as the triangulation extends, and have been connected with those executed by the party of Lieut. Comg. Maffitt in the Romerly marsh. For a distance of twenty-five miles up the Great Ogeechee, as far as the crossing of the Albany and Gulf railroad, there is much traffic carried on in small schooners, and this region produces its millions worth of rice and cotton, which finds its way through these inland waters to the Savannah market. It is desirable, therefore, that this river should be sounded out to the chief landing at the point of crossing above mentioned.

The bar buoy and the next one in turn (there having been originally five buoys in all) have not been in place during our sojourn here. The readjustment of them should be deferred until the reduction of our soundings, when the exact positions necessary for their occupations can be indicated. * * *

From a comparison with the hydrographic reconnaissance made of the channel-ways of Ossabaw by Captain Mackay, U. S. A., in 1846, it would seem that great changes have since then occurred, and all for the worse.

The seaward face of Ossabaw island has certainly undergone considerable change of feature since that portion of the shore-line embraced in my projection was executed. The triangulation point "north Ossabaw island No. 2" has washed away since the commencement of our survey, and the spot is now marked by a large tripod erected by my party.

* * * * * * * * *

Yours, very respectfully,

CHAS. M. FAUNTLEROY,
Lieut. Comg., U. S. N., Assistant Coast Survey.

Prof. A. D. BACHE, *Superintendent U. S. Coast Survey.*

APPENDIX No. 13.

Letter to the Secretary of the Treasury, descriptive of a new channel into Sapelo sound, developed by Lieut. Comg. C. M. Fauntleroy, U. S. N., Assistant Coast Survey.

COAST SURVEY OFFICE, *May* 12, 1860.

SIR: I send herewith an unfinished proof of a chart of Sapelo entrance, which I think will interest you. It shows a new channel into Sapelo, developed by the Coast Survey. The

hydrography is by Lieut. Comg. Fauntleroy, U. S. N., Assistant in the Coast Survey. Lieutenant Bent makes the comparison of the old and new channels as follows:

"The new channel crosses the bar three-quarters of a mile to the southward of the old one now in use, and has much the appearance as if it was forcing itself through the bar, which at this point is only about one hundred feet in width, and with eighteen feet of water upon its shoalest part, the soundings showing twenty feet on either side, and deepening gradually both to seaward and in-shore along the channel coast. There are eighteen feet of water on the bar, but only seventeen feet in the old channel. In the latter the bar is fully a mile in width, and the slightest deviation from the channel course would carry a vessel into sixteen or fifteen feet. The new channel, on the contrary, is wide, and the bar being so narrow affords great advantage to vessels of large draught."

I would respectfully request authority to publish the information in reference to this new channel.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. HOWELL COBB, *Secretary of the Treasury.*

APPENDIX No. 14.

Letter to the Secretary of the Treasury, with extracts from the report of Lieut. Comg. John Wilkinson, U. S. N., Assistant Coast Survey, relative to dangers to navigation on the Florida reef, off Long key and Grassy key.

COAST SURVEY OFFICE, *July* 7, 1860.

SIR: I have the honor to transmit, for the information of the Light-house Board, extracts from the report of Lieut. Comg. John Wilkinson, U. S. N., Assistant Coast Survey, with a sketch showing the position of Tennessee shoal, Florida reef, and also the position of a wreck off Grassy key, determined in the course of the season's work of his party in the steamer Corwin.

"A careful examination was made of Tennessee shoal, which is more properly a group of shoals bearing S. by E. (by compass) from the east end of Long key. The outer and most dangerous one, with only twelve feet of water on it, is upon an elbow of the reef, and so close to the edge of it that vessels bound to the westward, and keeping the shoal water close aboard, are in great danger of running upon it, as there is deep water (twenty fathoms) within a cable's length to the southward. Several vessels are said to have struck there, but it is almost impossible to obtain reliable information where such casualties occur upon this coast. It is certain, however, that the shoal receives its name from a ship that was wrecked there many years ago. As it would be impracticable to mark its place permanently by a beacon, I would respectfully suggest that a buoy with heavy moorings might stand, which would be a great aid to navigation through the straits."

* * * "In the course of the season's operations the position of a sunken wreck off Grassy key was determined. It lies in twelve feet water, on the northern edge of the Hawk channel, and bears south, by compass, distant about two miles from the middle of the key. As it is a dangerous obstacle to navigation, few even of the coasters knowing its exact locality, its position was marked by a pole as well secured as our means would permit. A buoy should be placed on the obstruction."

I would respectfully request that the enclosed tracing may be transmitted, with a copy of this communication, to the Light-house Board.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. HOWELL COBB, *Secretary of the Treasury.*

APPENDIX No. 15.

Letter to the Secretary of the Treasury, giving the position of a shoal spot recently formed off Warrington navy yard, (Pensacola,) as determined and communicated by Lieut. Comg. T. A. Craven, U. S. N.

NEW YORK, *November* 15, 1860.

SIR: I have the honor to communicate that having received information from S. Thayer Abert, esq., civil engineer, Pensacola navy yard, of the existence of a shoal spot in the channel leading into Pensacola bay, Lieut. T. A. Craven, U. S. N., commanding the U. S. steamer Mohawk, made an examination of it at my request, and reported the following result:

"The shoal, which has but 20 feet of water upon it at mean low water, lies SE. from the navy yard, and about midway between the main and Santa Rosa island.

"The following bearings from it determine its position, viz:

Hospital, (magnetic,) NW. ½ N.
Church, (magnetic,) N.
Chimney, (navy yard,) (magnetic,) NE. by N.
Fort McRae, (flag-staff,) (magnetic,) SW. by W. ¾ W.
Fort Pickens, " SW.

"This shoal is evidently of recent formation, and supposed to have been caused by a sunken tree or log."

I would respectfully request authority to publish this as a notice to mariners.

Very respectfully, yours,

A. D. BACHE,
Superintendent U. S. Coast Survey.

Hon. HOWELL COBB,
Secretary of the Treasury.

APPENDIX No. 16.

Tide tables for the use of navigators, prepared from the Coast Survey observations by A. D. Bache, Superintendent. (Furnished by authority of the Treasury Department to E. and G. W. Blunt, New York, and revised October, 1860.)

The following tables will enable navigators to ascertain the time and height of high and low water in some of the principal ports of the United States. The results are approximate, the observations being still in progress, but they may safely be used for practical purposes. The number of places of observation, and the time during which many of them have been made, are steadily on the increase as the Coast Survey advances.

The tides on the coast of the United States, on the Atlantic, Gulf of Mexico, and Pacific, are of three different classes. Those of the Atlantic are of the most ordinary type, ebbing and flowing twice in twenty-four hours, and having but moderate differences in height between the two successive high waters or low waters, one occurring before noon, the other after noon.

Those of the Pacific coast also ebb and flow twice during twenty-four hours, but the morning and afternoon tides differ very considerably in height, so much so that at certain periods a rock which has three feet and a half water upon it at low tide may be awash on the next succeeding low water. The intervals, too, between successive high and successive low waters may be very unequal.

The tides of ports in the Gulf of Mexico, west of Cape St. George, ebb and flow, as a rule, but once in twenty-four hours, or are single day tides. At particular parts of the month there are two small tides in the twenty-four hours. The rise and fall in all these ports is small. East of Cape St. George the rise and fall increases; there are two tides, as a rule, during the twenty-four hours, and the daily inequality referred to in the Pacific tides is large.

These peculiarities require a different way of treating the cases, and in some of them separate tables.

I propose to enable the navigator to find, from the Nautical Almanac and the following tables, the time and height of high and low water at any date within the ordinary range of difference produced by winds and other variable circumstances. I will endeavor to divest the matter of unfamiliar technical expressions as far as practicable, though for shortness' sake, some such terms may be employed after defining them. The discussion of the Gulf tides has not been carried so far as to enable me to present the results in as definite a form as the others.

As is well known, the interval between the time of the moon's crossing the meridian (moon's transit) and the time of high water at a given place is nearly constant; that is, this interval varies between moderate limits, which can be assigned. The interval at full and change of the moon is known as the establishment of the port, and is ordinarily marked on the charts. As it is not generally the average of the interval during a month's tides, it is a less convenient and less accurate quantity for the use of the navigation than the average interval which is used on the Coast Survey Charts, and is sometimes called the "mean" or "corrected establishment."* The following table gives the principal tidal quantities for the different ports named in the first column, where they are arranged under specific heads. The third column of the table gives the mean interval, in hours and minutes, between the moon's transit and the time of high water next after the transit; the fourth, the difference between the greatest and the least interval occurring in different parts of the month, (lunar.) A simple inspection of this column will show how important it is to determine these changes in many of the ports where they amount to more than half an hour, or to more than fifteen minutes from the average interval. The fifth, sixth, and seventh columns refer to the height of the tide. The fifth gives, in feet, the average rise and fall, or average difference between high and low water. The sixth gives the greatest difference commonly known as the rise and fall of spring tides; and the seventh the least difference known as the rise and fall of the neap tides.

The average duration of the flood or rising tide is given in the eighth column; of the ebb or falling tide in the ninth; and of the period during which the tide neither rises nor falls, or the "stand," in the tenth. The duration of the flood is measured from the middle of the stand at low water to the middle of the stand at high water, so that the whole duration from one high water to the next, or from one low water to the next, should be given by the sum of the numbers in the eighth and ninth columns. At most of these places given in the list a mark of reference has been established for the height of the tide. I have omitted the description of these marks, (except in the following localities,) as of no particular interest in this connection.

BENCH-MARKS.

Boston.—The top of the wall or quay at the entrance of the dry dock in the Charlestown navy yard, is fourteen feet $\frac{69}{100}$ (or 14.69 feet) above mean low water.†

New York.—The lower edge of a straight line cut in a stone wall, at the head of a wooden wharf on Governor's island, is thirteen feet $\frac{97}{100}$ (or 13.97 feet) above mean low water. The letters U. S. C. S. are cut in the same stone.

* This term was introduced by the Rev. Dr. Whewell, who has done so much for the investigation of the laws of the tides.

† In consequence of alterations made to the wall during the year 1860, the coping is seven hundredths of a foot lower than formerly.

Old Point Comfort, Va.—A line cut in the wall of the light-house, one foot from the ground, on the southwest side, is eleven feet (11 feet) above mean low water.

Charleston, S. C.—The outer and lower edge of embrasure of gun No. 3, at Castle Pinckney, is ten feet $\frac{13}{100}$ (10.13 feet) above mean low water.

TABLE I.

Tide table for the coast of the United States.

PORT.	STATE.	INTERVAL BETWEEN TIME OF MOON'S TRANSIT AND TIME OF HIGH WATER.		RISE AND FALL.			MEAN DURATION OF—		
		Mean interval.	Diff. between greatest and least int'val.	Mean.	Spring tides.	Neap tides.	Flood tide.	Ebb tide.	Stand.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
COAST FROM PORTLAND TO NEW YORK.		h. m.	h. m.	Feet.	Feet.	Feet.	h. m.	h. m.	h. m.
Hanniwell's Point, Kennebec river........	Maine............	11 15	1 14	8.1	9.3	7.0	6 16	6 11	0 22
Portland..............................	....do............	11 25	0 44	8.9	9.9	7.6	6 14	6 12	20
Portsmouth............................	New Hampshire....	11 23	53	8.6	9.9	7.2	6 22	6 7	21
Newburyport...........................	Massachusetts	11 22	50	7.8	9.1	6.6	5 16	7 9	24
Rockport	....do............	10 57	42	8.6	10.2	7.1	6 17	6 9	30
Salem.................................	....do............	11 13	50	9.2	10.6	7.6	6 19	6 6	6
Boston Light...........................	....do............	11 12	35	9.3	10.9	8.1	6 20	6 6	15
Boston	....do............	11 27	43	10.0	11.3	8.5	6 13	6 13	9
Plymouth..............................	....do............	11 19	51	10.2	11.4	9.0	6 13	6 17	29
Wellfleet	....do............	11 5	1 13	11.2	13.2	9.2	6 6	6 17	15
Provincetown*..........................	....do............	11 22	40	9.2	10.8	7.7	6 16	6 10	21
Monomoy..............................	....do......	11 58	37	3.8	5.3	2.6	6 25	5 59	36
Nantucket	....do............	12 24	37	3.1	3.6	2.6	6 23	5 44	9
Hyannis...............................	....do.......	12 22	30	3.2	3.9	1.8	6 44	5 41	9
Edgartown..............................	....do............	12 16	34	2.0	2.5	1.6	6 51	5.29	24
Holmes's Hole..........................	....do............	11 43	31	1.7	1.8	1.3	6 41	5 21	12
Tarpaulin Cove.........................	....do............	8 4	49	2.3	2.8	1.8	6 9	6 17	34
Wood's Hole, north side..................	....do............	7 59	53	4.0	4.7	3.1	6 51	5 31	38
Wood's Hole, south side	....do............	8 34	45	1 6	2.0	1.2	5 17	7 10	59
Menemsha Bight........................	....do............	7 45	1 0	2.7	3.9	1.8	6 14	6 14	4
Quick's Hole, north side	....do............	7 31	1 15	3.7	4.3	2.9	6 31	5 54	39
Quick's Hole, south side.................	....do............	7 36	1 10	3.1	3.8	2.3	6 29	5 55	40
Cuttyhunk.............................	....do............	7 40	49	3.5	4.2	2.9	6 31	5 54	39
Kettle Cove	....do............	7 48	1 0	4.3	5.0	3.7	6 17	6 4	29
Bird Island light........................	....do............	7 59	45	4.4	5.3	3.5	6 51	5 58	... .
New Bedford entrance, (Dumpling Rock).	....do............	7 57	41	3.8	4.6	2.8	6 50	5 33	42
Newport...............................	Rhode Island	7 45	24	3.9	4.6	3.1	6 21	6 3	23
Point Judith	....do............	7 32	46	3.1	3.7	2.6	6 12	6 10	1 0
Block Island...........................	....do..........	7 36	41	2.8	3.5	2.0	6 23	6 2	5
Montauk Point, L. I.....................	New York.........	8 20	1 11	1.9	2.4	1.8	6 17	6 7	31
Sandy Hook...........................	....do............	7 29	47	4.8	5.6	4.0	6 10	6 15	21
New York.............................	....do............	8 13	43	4.3	5.4	3.4	6 0	6 25	28
HUDSON RIVER.									
Dobb's Ferry	New York.........	9 19	44	3.6	4.4	2.7	6 5	6 18	17
Tarrytown............................	....do............	9 57	58	3.5	4.0	2.7	6 6	6 20	43
Verplanck's Point.......................	....do............	10 8	34	3.1	3.8	2.5	5 25	7 12	16
West Point............................	....do............	11 2	37	2.7	3.2	2.0	5 28	7 10	20
Poughkeepsie.........	....do............	12 34	54	3 2	3.9	2.4	5 41	6 44	22
Tivoli	....do............	1 24	51	4.0	4.6	3.2	5 40	6 54	25
Stuyvesant	....do............	3 23	48	3.8	4.4	3.0	5 18	7 2	31
Castleton	....do............	4 29	55	2.7	3.0	2.3	5 1	7 23	20
Greenbush.............................	....do.	5 22	40	2.3	2.5	1.9	4 26	7 59	....

* From Major J. D. Graham's observations.

TABLE I—Continued.

PORT.	STATE.	INTERVAL BETWEEN TIME OF MOON'S TRANSIT AND TIME OF HIGH WATER.		RISE AND FALL.			MEAN DURATION OF—		
		Mean interval.	Diff. between greatest and least int'val.	Mean.	Spring tides.	Neap tides.	Flood tide.	Ebb tide.	Stand.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
LONG ISLAND SOUND.		h. m.	h. m.	Feet.	Feet.	Feet.	h. m.	h. m.	h. m.
Watch Hill	Rhode Island	9 0	0 23	2.7	3.1	2.4	6 35	5 56	0 14
Stonington	Connecticut	9 7	30	2.7	3.2	2.2	6 15	6 10	25
Little Gull island	New York	9 38	1 07	2.5	2.9	2.3	6 1	6 21	37
New London	Connecticut	9 28	52	2.6	3.1	2.1	5 56	6 26	22
New Haven	....do	11 16	1 8	5.9	6.2	5.2	6 24	6 5	33
Bridgeport	....do	11 11	1 3	6.5	8.0	4.7	6 1	6 7	30
Oyster Bay, L. I.	New York	11 7	51	7.3	9.2	5.4	6 8	6 24	25
Sand's Point, L. I.	....do	11 13	31	7.7	8.9	6.4	5 55	6 30	14
New Rochelle	....do	11 22	32	7.6	8.6	6.6	5 51	6 35	12
Throg's Neck	....do	11 20	39	7.3	9.2	6.1	5 50	6 33	43
COAST OF NEW JERSEY.									
Cold Spring inlet	New Jersey	7 32	51	4.4	5.4	3.6	6 8	6 18	19
Cape May landing	....do	8 19	47	4.8	6.0	4.3	6 11	6 15	20
DELAWARE BAY AND RIVER.									
Delaware breakwater	Delaware	8 0	50	3.5	4.5	3.0	6 15	6 6	26
Higbee's, Cape May	New Jersey	8 33	43	4.9	6.2	3.9	6 26	6 0	19
Egg Island light	do	9 4	51	6.0	7.0	5.1	5 52	6 27	36
Mahon's river	Delaware	9 52	48	5.9	6.9	5.0	6 11	6 11	26
Newcastle	....do	11 53	24	6.5	6.9	6.6	5 6	6 43	47
Philadelphia	Pennsylvania	13 44	44	6.0	6.8	5.1	4 52	7 6	15
CHESAPEAKE BAY AND RIVERS.									
Old Point Comfort	Virginia	8 17	60	2.5	3.0	2.0	6 1	6 25	14
Point Lookout	Maryland	12 58	45	1.4	1.9	0.7	5 59	6 19	35
Annapolis	....do	17 4	40	0.9	1.0	0.8	6 11	6 15	32
Bodkin light	....do	18 8	48	1.0	1.3	0.8	5 23	7 8	15
Baltimore	....do	18 59	44	1.3	1.5	0.9	5 54	6 33	44
Washington	Dist. of Columbia	20 10	52	3.0	3.4	2.6	5 37	6 49	....
James river, (City Point)	Virginia	14 37	1 0	2.8	3.0	2.5	5 14	6 58	32
Richmond	....do	16 54	1 6	2.9	3.4	2.3	4 53	7 31	35
Tappahannock	....do	12 58	46	1.6	1.9	1.3	5 21	7 6	....
COAST OF NORTH AND SOUTH CAROLINA, GEORGIA, AND FLORIDA.									
Hatteras Inlet	North Carolina	7 4	57	2.0	2.2	1.8	6 7	6 7	50
Beaufort	....do	7 26	50	2.8	3.3	2.2	6 11	6 10	42
Bald Head	....do	7 26	34	4.3	5.0	3.4	6 18	6 17	31
Smithville	... do	7 19	38	4.5	5.5	3.8	6 1	6 26	26
Wilmington	....do	9 6	1 0	2.7	3.1	2.2	4 45	7 40	30
Georgetown entrance	South Carolina	7 56	42	3.8	4.7	2.7	6 4	6 19	35
Bull's Island bay	....do	7 16	57	4.8	5.7	3.7	6 20	6 6	30
Charleston, (custom-house wharf)	....do	7 26	48	5.1	6.0	4.1	6 19	6 7	33
St. Helena Sound	....do	7 8	1 0	5.9	7.4	4.4	6 13	6 12	23
Fort Pulaski, (Savannah entrance)	Georgia	7 20	40	7.0	8.0	5.9	5 49	6 35	26
Savannah, (dry dock wharf)	....do	8 13	51	6.5	7.6	5.5	5 4	7 22	14
Doboy Light-house	....do	7 33	55	6.6	7.8	5.4	6 2	6 20	....
St. Simons	....do	7 43	46	6.8	8.2	5.4	6 10	6 16	20
Fort Clinch	Florida	7 53	1 6	5.9	6.7	5.3	6 9	6 17	....
St. John's river	....do	7 28	48	4.5	5.5	3.7	5 58	6 28	16
St. Augustine	....do	8 21	43	4.2	4.9	3.6	6 5	6 11	32
Cape Florida	....do	8 34	51	1.5	1.8	1.2	6 0	6 26	45
Indian key	....do	8 23	49	1.8	2.2	1.3	6 25	5 59	19
Sand key	....do	8 40	....	1.2	2.0	0.6	6 31	5 55	13

TABLE I—Continued.

PORT.	STATE.	Interval between time of moon's transit and time of high water.		Rise and fall.			Mean duration of—		
		Mean interval.	Diff. between greatest and least int'val.	Mean.	Spring tides.	Neap tides.	Flood tide.	Ebb tide.	Stand.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
COAST OF NORTH AND SOUTH CAROLINA, GEORGIA AND FLORIDA—Continued.		h. m.	h. m.	Feet.	Feet.	Feet.	h m.	h. m.	h. m.
Key West	Florida	9 30	1 15	1.3	1.5	0.9	6 55	5 29	0 12
Tortugas	....do	9 56	1 32	1.2	1.5	0.6	6 43	5 40	....
Tampa Bay, (Egmont key)	....do	11 21	1 33	1.4	1.8	1.0	6 36	6 11	43
Cedar Keys, (Depot key)	....do	13 15	1 55	2.6	3.2	1.6	6 12	6 13	....
St. Mark's	....do	13 38	2 0	2.2	2.9	1.4	6 12	6 11	....
WESTERN COAST.									
San Diego	California	9 38	1 35	3.7	5.0	2.3	6 22	6 0	30
San Pedro	....do	9 39	1 48	3.7	4.7	2.2	6 18	6 5	30
Cuyler's harbor	....do	9 25	1 2	3.7	5.1	2.8	6 13	6 5	....
San Luis Obispo	....do	10 8	1 52	3.6	4.8	2.4	6 25	5 58	....
Monterey	....do	10 22	49	3.4	4.3	2.5	6 31	6 2	35
South Farallone	....do	10 37	1 16	3.6	4.4	2.8	6 18	6 9	....
San Francisco, (north beach)	....do	12 6	1 4	3.6	4.3	2.8	6 39	5 51	34
Mare Island, (San Francisco bay)	....do	13 40	1 15	4.8	5.2	4.1	6 13	6 7	....
Benicia	....do	14 10	1 0	4.5	5.1	3.7	6 26	5 59	....
Ravenswood	....do	12 36	57	6.3	7.3	4.9	6 15	6 11	....
Bodega	....do	11 17	1 54	3.6	4.7	2.7	6 19	5 59	....
Humboldt bay	....do	12 2	1 11	4.4	5.5	3.5	6 19	6 0	....
Port Orford	Oregon Territory	11 26	1 6	5.1	6.8	3.7	6 19	6 7	39
Astoria	....do	12 42	1 13	6.1	7.4	4.6	6 3	6 28	33
Nee-ah harbor	Washington Ter'y	12 33	1 28	5.6	7.4	4.8	6 20	6 6	....
Port Townshend*	....do	3 49	1 3	4.6	5.5	4.0	6 34	5 52	....
Steilacoom*	....do	4 46	1 6	9.2	11.1	7.2	6 3	6 25	28
Semi-ah-moo bay*	....do	4 50	1 2	5.7	6.6	4.8	6 11	6 19	26

* See remarks on page 144 and following.

Note.—The mean interval in column 3 has been increased by 12*h.* 26*m.*, (half a mean lunar day,) for some of the ports in Delaware river and Chesapeake bay, so as to show the succession of times from the mouth. Therefore 12*h.* 26*m.* ought to be subtracted from the establishments which are greater than that quantity before using them.

The foregoing Table I gives the means of determining, roughly, the time and height of high water at the several ports named. The hour of transit of the moon preceding the time of high water is to be taken from the Almanac, and the mean establishment being added the time of high water results. Thus:

Example I.—It is required to find the time of high water at New York on November 5, 1854. The American Almanac gives 0*h.* 0*m.* as the time of transit of the moon on that day. The mean interval for New York, from Table I, column 3, is 8*h.* 13*m.*, which, as the transit was at 0*h.*, is, roughly, the time of high water. The moon being full, the height is that of spring tides of column 6, viz: 5.4 feet. If the soundings on the chart are reduced to low water spring tides, 5.4 feet are to be added to them to give the depth at high water. If the soundings are reduced to mean low water, the rise and fall of mean tides being 1.1 foot less than for springs, the rise or increase of depth will be half of this, or 0.6 of a foot less than 5.4 feet, which is 4.8 feet, or nearly four feet ten inches.

Example II.—Required the time of high water at Boston on January 23, 1851. From the

American Almanac we find the time of the moon's southing or transit on that day 5*h.* 18*m.* a. m., and from Table I the mean interval at Boston dry dock is 11*h.* 27*m.*

We have then	5*h.*	18*m.*	time of transit.
To which add	11	27	mean interval from Table I.
	16	45	time of high water, or 4*h.* 45*m.* p. m.

If the Greenwich Nautical Almanac is used, add 2*m.* to the time of transit of Greenwich for every hour of west longitude and its proportional part for less than an hour. It will suffice to take the half hour which may be over any number of hours, as the correction for less than this would be less than one minute, and need not be taken into account. Thus, Boston is 4*h.* 44*m.* west of Greenwich. The correction to be applied to the time of transit of the moon is, for the four hours, eight minutes, and for the forty-four minutes, one minute. The time of transit on the date assumed in the preceding example is 17*h.* 9*m.* of the 22d, or 5*h.* 9*m.* a. m. of the 23d, to which add nine minutes; the correction just found gives 5*h.* 18*m.*, as before ascertained from the American Almanac.

In using the United States Nautical Almanac, in the astronomical part of which the transits of the moon are given for the meridian of Washington, the corrections required may, in this first approximation for the Atlantic coast, be neglected. To find the time of the next following low water add, from Table I, the duration of ebb tide.

This gives	4*h.*	45*m.*	p. m. time of high water.
	6	13	duration of ebb tide from Table I.
	10	58	p. m.

By subtracting the duration of flood tide we obtain the time of the preceding low water, 10*h.* 32*m.* a. m., recollecting that 4*h.* 45*m.* p. m. is the same as 16*h.* 45*m.* reckoned from midnight.

The height of this tide, corresponding to the transit of 5*h.*, will bring it nearly to a neap tide, and the rise and fall obtained from column 7, Table I, is 8.5 feet. The next following high water may be had by adding to the time of low water the duration of flood from Table I. Thus:

	10*h.*	58*m.*	p. m. time of low water January 23.
	6	13	duration of flood from Table I.
Sum	17	11	or 5*h.* 11*m.* on January 24.

Or, having found the time of high water the time of the next following high water may be found by adding the duration of flood and ebb together, and their sum to the time of high water found, thus:

	6*h.*	13*m.*	duration of ebb tide, from Table I.
	6	13	duration of flood.
Sum	12	26	duration of whole tide.
	4	45	p. m., January 23, time of high water.
Sum	17	11	or 5*h.* 11*m.* a. m., January 24, time of the next succeeding high water.

Subtracting the same quantity will give the time of the preceding high water, thus:

4*h.*	45*m.*	p. m., or 16*h.* 45*m.* from midnight, is the time of high water.
12	26	duration of flood and ebb tide.
4	19	a. m. of the 23d for the preceding high water.

The duration of the flood and the ebb being reckoned from the middle of one stand or slack water to the middle of the next, the time of beginning of stand of ebb or flood will be found by subtracting half the duration of stand or slack water given by column 10, Table I, from the

time of high or low water, and the time of the end of the stand of ebb or flood by adding the same. A nearer approximation to the times and heights of high water may be obtained by the use of Tables II and III.

TABLE II.

Interval between the time of moon's transit and the time of high water for different hours of transit, and for several different ports.

Time of moon's transit.	Boston, Mass.	New York, N. Y.	Philadelphia, Pa.	Old Pt. Comfort, Va.	Baltimore, Md.	Smithville, N. C.	Charleston, S. C.	Ft. Pulaski, Savannah, Ga.	Key West, Fla.	San Francisco, Cal.
h. m.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
0 0	11 38	8 20	1 31	8 33	6 47	7 26	7 38	7 30	9 33	12 5
0 30	11 33	8 18	1 28	8 27	6 42	7 21	7 33	7 25	9 26	11 59
1 0	11 28	8 15	1 25	8 21	6 37	7 16	7 27	7 19	9 19	11 53
1 30	11 24	8 10	1 21	8 15	6 31	7 13	7 21	7 15	9 13	11 47
2 0	11 20	8 6	1 18	8 9	6 26	7 9	7 16	7 11	9 6	11 41
2 30	11 16	8 0	1 14	8 4	6 21	7 6	7 12	7 8	9 1	11 36
3 0	11 13	7 55	1 11	8 0	6 17	7 4	7 8	7 6	8 57	11 33
3 30	11 10	7 52	1 8	7 56	6 13	7 3	7 5	7 5	8 53	11 33
4 0	11 7	7 52	1 6	7 52	6 11	7 2	7 2	7 4	8 53	11 38
4 30	11 6	7 52	1 3	7 49	6 10	7 3	7 2	7 3	8 56	11 46
5 0	11 6	7 53	1 0	7 48	6 10	7 4	7 3	7 4	9 2	11 55
5 30	11 9	7 56	0 59	7 50	6 13	7 6	7 7	7 6	9 10	12 3
6 0	11 13	7 59	0 59	7 53	6 19	7 9	7 12	7 8	9 22	12 11
6 30	11 19	8 5	1 1	8 0	6 25	7 13	7 19	7 12	9 33	12 16
7 0	11 25	8 11	1 7	8 7	6 32	7 17	7 24	7 16	9 49	12 23
7 30	11 32	8 17	1 15	8 15	6 39	7 23	7 32	7 22	10 0	12 29
8 0	11 38	8 23	1 23	8 24	6 44	7 28	7 38	7 28	10 6	12 34
8 30	11 43	8 27	1 29	8 33	6 49	7 33	7 45	7 34	10 7	12 37
9 0	11 47	8 32	1 34	8 40	6 52	7 37	7 48	7 39	10 6	12 36
9 30	11 48	8 34	1 39	8 45	6 54	7 39	7 50	7 42	10 3	12 34
10 0	11 49	8 35	1 42	8 48	6 53	7 40	7 50	7 43	9 59	12 30
10 30	11 48	8 34	1 43	8 48	6 52	7 40	7 47	7 41	9 56	12 24
11 0	11 47	8 31	1 41	8 46	6 50	7 36	7 44	7 37	9 48	12 17
11 30	11 43	8 25	1 37	8 40	6 48	7 30	7 41	7 34	9 40	12 9

TABLE III.

Showing the rise and fall of tides, and corrections to be applied to determine the depth at high water of soundings on charts referred to mean low water, and to low water spring tides.

Time of moon's transit.	Boston, Mass.			New York, N. Y.			Philadelphia, Pa.			Old Point Comfort, Va.			Baltimore, Md.			Time of moon's transit.
	A,	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Hour.*
0	11.2	10.6	11.3	4.9	4.5	4.9	6.3	6.2	6.3	2.9	2.6	2.9	1.5	1.4	1.6	0
1	11.3	10.6	11.3	4.9	4.5	4.9	6.4	6.4	6.5	3.0	2.7	3.0	1.5	1.4	1.6	1
2	11.2	10.5	11.2	4.7	4.4	4.8	6.6	6.5	6.6	2.9	2.7	2.9	1.5	1.3	1.5	2
3	10.6	10.3	10.0	4.3	4.2	4.6	6.6	6.5	6.6	2.6	2.6	2.8	1.4	1.3	1.5	3
4	10.0	10.0	10.7	3.8	4.0	4.4	6.4	6.4	6.5	2.3	2.4	2.7	1.3	1 2	1.4	4
5	9.2	9.7	10.4	3.5	3.8	4.2	6.1	6.2	6.3	2.1	2.3	2.6	1.1	1.1	1.3	5
6	8.8	9.4	10.1	3.3	3.7	4.1	5.7	5.9	6.0	2.0	2.2	2.5	0.9	1.1	1.3	6
7	8.6	9 3	10.0	3.3	3.7	4.1	5.4	5.6	5.7	2.0	2.3	2.5	0.9	1.1	1.3	7
8	8.9	9.5	10.2	3.6	3.8	4.2	5.2	5.3	5.4	2.2	2.4	2.6	1.0	1.2	1.4	8
9	9.4	9.7	10.4	4.0	4.0	4.4	5.4	5.4	5.5	2.5	2.5	2.8	1.1	1.3	1.5	9
10	10.1	10.0	10.7	4.5	4.3	4.7	5.7	5.7	5.8	2.8	2.7	2.9	1.3	1.4	1.6	10
11	10.7	10.3	11.0	4.8	4.5	4.9	6.0	6.0	6.1	3.0	2.8	3.0	1.4	1.4	1.6	11

TABLE III—Continued.

Time of moon's transit.	Smithville, N. C.			Charleston, S. C.			Fort Pulaski, Savannah entrance.			Key West, Fla.			San Francisco, Cal.			Time of moon's transit.
	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Hour.*
0	5.2	4.8	5.1	6.0	5.5	6.0	7.8	7.4	7.8	1.5	1.4	1.5	4.5	4.0	4.4	0
1	5.1	4.8	5.1	5.9	5.5	5.9	7.9	7.4	7.9	1.5	1.4	1.5	3.9	3.7	4.1	1
2	5.0	4.7	5.0	5.7	5.4	5.8	7.6	7.3	7.7	1.5	1.4	1.5	3.7	3.6	4.1	2
3	4.6	4.5	4.8	5.3	5.2	5.6	7.1	7.0	7.5	1.4	1.3	1.4	3.5	3.5	4.0	3
4	4.3	4.4	4.7	4.7	4.9	5.4	6.5	6.7	7.2	1.2	1.2	1.3	3.1	3.3	3.8	4
5	4.0	4.3	4.6	4.4	4.8	5.2	6.1	6.5	7.0	1.0	1.1	1.2	2.8	3.1	3.6	5
6	3.8	4 2	4.5	4.2	4.6	5.1	5.8	6.4	6.8	0.9	1.0	1.1	2.7	3.1	3.6	6
7	3.8	4.1	4.4	4.3	4.7	5.1	6.0	6.5	6.9	0.9	1.1	1.2	3.0	3.3	3.7	7
8	4.0	4.2	4.5	4.5	4.8	5.3	6.4	6.7	7.1	1.0	1.2	1.3	3.4	3.5	3.9	8
9	4.3	4.3	4.6	5.0	5.0	5.5	6.9	6.9	7.4	1.2	1.3	1.4	3.8	3.6	4.1	9
10	4.7	4.6	4.9	5.5	5.3	5.8	7.4	7.0	7.6	1.4	1.4	1.5	4.0	3.8	4.2	10
11	5.0	4.7	5.0	5.9	5.5	5.9	7.8	7.2	7.8	1.5	1.4	1.5	4.2	3.8	4.3	11

In these the variations in the interval between the moon's transit and high water are shown for some of the principal ports contained in Table I. These variations of intervals depend upon the age of the moon, and, as they go through their values in half a lunar month, are known as the half-monthly inequality of interval. The table extends from the 0*h.* of transit, midnight of the calendar day, or full of the moon, to 11½ hours. The numbers for change of the moon correspond to those of 0*h.*, and for 13 hours (or 1*h.* p. m. of the calendar day) to 1 hour, and so on up to 23 hours. The ports for which the numbers are given are designated by the heading of the column.

The mean interval, it will be seen, does not occur at full and change, but nearly two days afterwards, on the Atlantic coast. At Key West it occurs more nearly at full and change, and at San Francisco still more nearly.

The same remark applies to the heights; spring tides occur about two days after the full and change of the moon, and neaps two days after the first and last quarters. The use of this table of nearer approximation is quite as simple as that of Table I.

Rule to find the time of high water.—Look in the Almanac for the time of moon's transit (or southing) for the date required. In the table corresponding to that time will be found the number to be added to the time of transit.

Example III.—Required the time of high water at New York October 1, 1856. Using the United States Nautical Almanac we find the time of moon's transit 1*h.* 24*m.* astronomical reckoning, or 1*h.* 24*m.* p. m. calendar time. From Table II we have, under the heading of New York, for 1*h.* 30*m.* (the nearest number to 1*h.* 24*m.* in the table) 8*h.* 10*m.*

Thus, to	1*h.*	24*m.*,	time of moon's transit,
Add	8	10	interval found in Table III.
The sum	9	34	p. m. is the time of high water on the 1st of October, 1856.

If the sum of these numbers had exceeded twelve, the tide would have belonged to October 2, and we must have gone back to the transit of the day before and computed with it to obtain the tide of October 1.

Rule to find the height of high water.—Enter Table III, column 1, with the time of moon's transit. In the column headed with the name of the place, and marked A, will be found the rise and fall corresponding to the time of transit; in column B the number to be added to soundings on the chart, where the soundings are given for mean low water; in column C the number to be added to charts of which the soundings are given for low water spring tides.

In the foregoing example (III) the time of transit being 1 and 2 hours, we find from Table

III the rise and fall of tides on the 1st of October, 1856, between 4.9 and 4.7; the number to be added to soundings given for mean low water 4.5 feet, (column B,) and for low water spring tides (column C) 4.9 feet.

Having found the time of high water, that of low water may be obtained, nearly, by adding the duration of ebb from column 9, Table I. The time of the next preceding low water may be found by subtracting the duration of flood from column 8, Table I. The time of the next following high water may be found by adding the duration of both flood and ebb; and of the next preceding high water by subtracting the same duration of the whole tide.

Example IV.—To find the next high water following that of Example III.

The duration of flood, column 8, Table I, for New York is 6*h.* 0*m.*, and of ebb, from column 9, is 6*h.* 25*m.*; the sum is 12*h.* 25*m.*

To	9*h.*	34*m.*	p. m., October 1, time of high water found,
Add	12	25	duration of flood and ebb.
Sum	21	59	or 9*h.* 59*m.* a. m. of October 2, the time of the next high water.

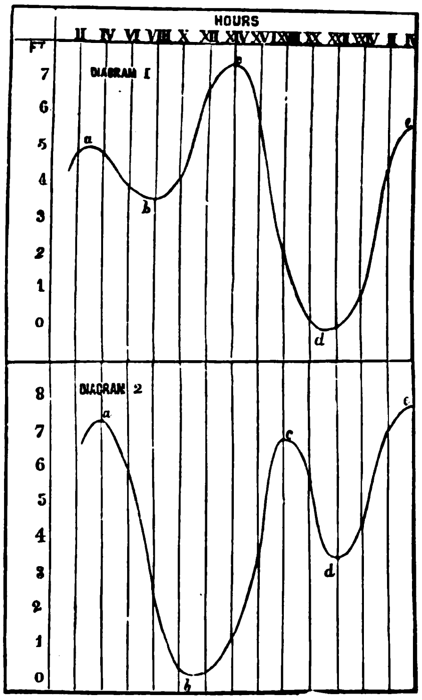
TIDES OF THE PACIFIC COAST AND OF PART OF THE COAST OF FLORIDA.

On the Pacific coast there are, as a general rule, one large and one small tide during the day, the height of the two successive high waters occurring one a. m. the other p. m. of the same twenty-four hours, and the intervals from the next preceding transit of the moon are very different. The inequalities depend upon the moon's declination; they disappear near the time of the moon's declination being nothing, and are greatest about the time of its being greatest. The inequalities for low water are not the same as for high, though they disappear and have the greatest value at nearly the same times. The tides of the southern part of Florida and of the western coast of that peninsula, as far as St. Mark's, are of the same character.

In Puget's sound the inequalities for the interval of high water and for the height of low water follow this rule; but those for the interval of low water and height of high water disappear about one day before the moon's declination is greatest, and are greatest about four or five days before the greatest declination.

When the moon's declination is north, the highest of the two tides of the twenty-four hours occurs at San Francisco about eleven and a half hours after the moon's southing, (transit;) and when the declination is south, the lowest of the two high tides occurs about that interval.

The lowest of the two low waters of the day is one which follows next the highest high water. The nature of these tides will probably appear more plainly from the annexed diagrams. In them the height of the tide is set off at the side on a scale of feet, and the hours of the day are at the top. At 12 noon, for example, the tide-gauge marked 6.7 feet. Joining all the heights observed in the twenty-four hours we have a curve like that marked in the figure. The two high waters are *a* and *c*, the two low waters *b* and *d*. If *a* is the high water which occurs about twelve hours after the transit of the moon, when the declination is south, the ebb *a b* is quite small, and the high water, *a*, is much lower than the next high water, *c*. If the moon's declination is north, it is the large high water, *a*, of the second diagram which occurs next after the transit, and about twelve hours from it. At Key West the contrary obtains, diagram 1 applying when the moon's declination is north, and diagram 2 when south. Tables IV and V give the number to be added to the time of moon's transit to find the time of high water almost as readily as in the former case. They are of double entry, the time of transit being, as before, placed in the first column. The number of days from the day at which the moon had the greatest declination is arranged at the top of the table. Entering the first column with the time of transit, and following the line horizontally until we come under the column containing the days from



the greatest declination, we find the number to be added to the time of the transit to give time of high water. If the moon's declination is south, Table IV is to be used; if north, Table V.

Tables IV to IX, inclusive, have been recomputed, using more complete data for the inequalities above referred to, and to those for San Francisco similar tables have been added for San Diego, Astoria, Port Townshend, and Key West, Fla. For the other places on the Western Coast given in Table I the following rules will give sufficiently close approximations.

To obtain the times of high or low water for San Pedro, Cuyler's harbor, and San Luis Obispo, compute first the time for San Diego by Tables IV, V, or VIII; then add to the time thus obtained 30 minutes to obtain the time for San Luis Obispo, and subtract 13 minutes for Cuyler's harbor. At San Pedro the time of high or low water is sensibly the same as at San Diego.

For Monterey, South Farallone, Mare Island, Benicia, Ravenswood, and Bodega, compute first the time for San Francisco, then subtract from the time thus obtained 1*h.* 44*m.* for Monterey, 1*h.* 29*m.* for the South Farallon, and 49*m.* for Bodega; and add 34*m.* for Mare island, 1*h.* 4*m.* for Benicia, and 30*m.* for Ravenswood. For Humboldt bay, Port Orford, and Neeah harbor, compute first the time for Astoria, then subtract from it 40*m.* for Humboldt bay, 1*h.* 16 *m.* for Port Orford, and 9*m.* for Neeah harbor.

For Steilacoom and Semiahmoo bay, compute first the time for Port Townshend, and add to it 57*m.* for Steilacoom, and 1*h.* for Semiahmoo. The approximation will be only a rough one for Steilacoom.

For the heights, Tables VI, VII, and IX for San Diego can be used without change for San Pedro, Cuyler's harbor, and San Luis Obispo. These tables for San Francisco are also applicable to Monterey, South Farallon, and Bodega. For Mare island add 1.2 foot, for Benicia, 0.9 foot, and for Ravenswood, 2.7 feet to the quantities for San Francisco.

For Humboldt bay, Port Orford, and Neeah harbor, the tables for Astoria may be used, subtracting 1.7 foot for Humboldt bay, and 1.0 foot for Port Orford. For Neeah harbor the tables will give approximate results without change.

For Semiahmoo bay, add one foot to the quantities in the tables for Port Townshend. For Steilacoom, a rough approximation may be obtained by adding 4.6 feet to them.

For the coast of Florida, compute the times of high or low water for Key West, and subtract 12*m.* for Indian key, and add 26*m.* for Tortugas and 1*h.* 51*m.* for Egmont key, 3*h.* 45*m.* for Cedar keys, and 4*h.* 8*m.* for St. Mark's. For the heights, add half a foot for Indian key, and use the tables without change for Tortugas and Egmont key. For Cedar keys and St. Mark's, the results could not be obtained with much accuracy in this way; special tables will be prepared for those places.

TABLE IV.—KEY WEST.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0 00	9 40	9 30	9 18	9 07	9 01	8 49	8 44	8 40	8 40	8 46	8 54	9 06	9 16	9 27	9 37
0 30	9 33	9 23	9 11	9 00	8 54	8 42	8 37	8 33	8 33	8 39	8 47	8 59	9 09	9 20	9 30
1 00	9 26	9 16	9 04	8 53	8 47	8 35	8 30	8 26	8 26	8 32	8 40	8 52	9 02	8 13	9 23
1 30	9 20	9 10	8 58	8 47	8 41	8 29	8 24	8 20	8 20	8 26	8 34	8 46	8 56	9 07	9 17
2 00	9 13	9 03	8 51	8 40	8 34	8 22	8 17	8 13	8 13	8 19	8 27	8 39	8 49	9 00	9 10
2 30	9 08	8 58	8 46	8 35	8 29	8 17	8 12	8 08	8 08	8 14	8 22	8 34	8 44	8 55	9 05
3 00	9 04	8 54	8 42	8 31	8 25	8 13	8 08	8 04	8 04	8 10	8 18	8 30	8 40	8 51	9 01
3 30	9 00	8 50	8 38	8 27	8 21	8 09	8 04	8 00	8 00	8 06	8 14	8 26	8 36	8 47	8 57
4 00	9 00	8 50	8 38	8 27	8 21	8 09	8 04	8 00	8 00	8 06	8 14	8 26	8 36	8 47	8 57
4 30	9 03	8 53	8 41	8 30	8 24	8 12	8 07	8 03	8 03	8 09	8 17	8 29	8 39	8 50	9 00
5 00	9 09	8 59	8 47	8 36	8 30	8 18	8 13	8 09	8 09	9 15	8 23	8 35	8 45	8 56	9 06
5 30	9 17	9 07	8 55	8 44	8 38	8 26	8 21	8 17	8 17	8 23	8 31	8 43	8 53	9 04	9 14
6 00	9 29	9 19	9 07	8 56	8 50	8 38	8 33	8 29	8 29	8 35	8 43	8 55	9 05	9 16	9 26
6 30	9 40	9 30	9 18	9 07	9 01	8 49	8 44	8 40	8 40	8 46	8 54	9 06	9 16	9 27	9 37
7 00	9 56	9 46	9 34	9 23	9 17	9 05	9 00	8 56	8 56	9 02	9 10	9 22	9 32	9 43	9 53
7 30	10 07	9 57	9 45	9 34	9 28	9 16	9 11	9 07	9 07	9 13	9 21	9 33	9 43	9 54	10 04
8 00	10 13	10 03	9 51	9 40	9 34	9 22	9 17	9 13	9 13	9 19	9 27	9 39	9 49	10 00	10 00
8 30	10 14	10 04	9 52	9 41	9 35	9 23	9 18	9 14	9 14	9 20	9 28	9 40	9 50	10 01	10 11
9 00	10 13	10 03	9 51	9 40	9 34	9 22	9 17	9 13	9 13	9 19	9 27	9 39	9 49	10 00	10 10
9 30	10 10	10 00	9 48	9 37	9 31	9 19	9 14	9 10	9 10	9 16	9 24	9 36	9 46	9 57	10 07
10 00	10 06	9 56	9 44	9 33	9 27	9 15	9 10	9 06	9 06	9 12	9 20	9 32	9 42	9 53	10 03
10 30	10 03	9 53	9 41	9 30	9 24	9 12	9 07	9 03	9 03	9 09	9 17	9 29	9 39	9 50	10 00
11 00	9 55	9 45	9 33	9 22	9 16	9 04	8 59	8 55	8 55	9 01	9 09	9 21	9 31	9 42	9 52
11 30	9 47	9 37	9 25	9 14	9 08	8 56	8 51	8 47	8 47	8 53	9 01	9 13	9 23	9 34	9 44

TABLE V.—KEY WEST.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0 0	9 29	9 36	9 43	9 53	10 06	10 16	10 22	10 22	10 22	10 18	10 06	9 56	9 43	9 34	9 27
0 30	9 22	9 29	9 36	9 46	9 59	10 09	10 15	10 15	10 15	10 11	9 59	9 49	9 36	9 27	9 20
1 0	9 15	9 22	9 29	9 39	9 52	10 02	10 08	10 08	10 08	10 04	9 52	9 42	9 29	9 20	9 13
1 30	9 09	9 16	9 23	9 33	9 46	9 56	10 02	10 02	10 02	9 58	9 46	9 36	9 23	9 14	9 07
2 0	9 02	9 09	9 16	9 26	9 39	9 49	9 55	9 55	9 55	9 51	9 39	9 29	9 16	9 07	9 00
2 30	8 57	9 04	9 11	9 21	9 34	9 44	9 50	9 50	9 50	9 46	9 34	9 24	9 11	9 02	8 55
3 0	8 53	9 00	9 07	9 17	9 30	9 40	9 46	9 46	9 46	9 42	9 30	9 20	9 07	8 58	8 51
3 30	8 49	8 56	9 03	9 13	9 26	9 36	9 42	9 42	9 42	9 38	9 26	9 16	9 03	8 54	8 47
4 0	8 49	8 56	9 03	9 13	9 26	9 36	9 42	9 42	9 42	9 38	9 26	9 16	9 03	8 54	8 47
4 30	8 52	8 59	9 06	9 16	9 29	9 39	9 45	9 45	9 45	9 41	9 39	9 29	9 06	8 57	8 50
5 0	8 58	9 05	9 12	9 22	9 35	9 45	9 51	9 51	9 51	9 47	9 35	9 25	9 12	9 08	8 56
5 30	9 06	9 13	9 20	9 30	9 43	9 53	9 59	9 59	9 59	9 55	9 43	9 33	9 20	9 11	9 04
6 0	9 18	9 25	9 32	9 42	9 55	10 05	10 11	10 11	10 11	10 07	9 55	9 45	9 32	9 23	9 16
6 30	9 29	9 36	9 43	9 53	10 06	10 16	10 22	10 22	10 22	10 18	10 06	9 56	9 43	9 34	9 27
7 0	9 45	9 52	9 59	10 09	10 22	10 32	10 38	10 38	10 38	10 34	10 22	10 12	9 59	9 50	9 43
7 30	9 56	10 03	10 10	10 20	10 33	10 43	10 49	10 49	10 49	10 45	10 33	10 23	10 10	10 01	9 54
8 0	10 02	10 09	10 16	10 26	10 39	10 49	10 55	10 55	10 55	10 51	10 39	10 29	10 16	10 07	10 00
8 30	10 03	10 10	10 17	10 27	10 40	10 50	10 56	10 56	10 56	10 52	10 40	10 30	10 17	10 08	10 01
9 0	10 02	10 09	10 16	10 26	10 39	10 49	10 55	10 55	10 55	10 51	10 39	10 29	10 16	10 07	10 00
9 30	9 59	10 06	10 13	10 23	10 36	10 46	10 52	10 52	10 52	10 48	10 36	10 26	10 13	10 04	9 57
10 0	9 55	10 02	10 09	10 19	10 32	10 42	10 48	10 48	10 48	10 44	10 32	10 22	10 09	10 00	9 53
10 30	9 52	9 59	10 06	10 16	10 29	10 39	10 45	10 45	10 45	10 41	10 29	10 19	10 06	9 57	9 50
11 0	9 44	9 51	9 58	10 08	10 21	10 31	10 37	10 37	10 37	10 33	10 21	10 11	9 58	9 49	9 42
11 30	9 36	9 43	9 50	10 00	10 13	10 23	10 29	10 29	10 29	10 25	10 13	10 03	9 50	9 41	9 34

TABLE IV.—SAN DIEGO.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0 0	9 25	9 40	9 52	10 3	10 12	10 20	10 25	10 29	10 29	10 25	10 19	10 10	10 0	9 47	9 30
0 30	9 15	9 30	9 42	9 53	10 2	10 10	10 15	10 19	10 19	10 15	10 9	10 0	9 50	9 27	9 20
1 0	9 8	9 23	9 35	9 46	9 55	10 3	10 8	10 12	10 12	10 8	10 2	9 53	9 43	9 30	9 13
1 30	9 1	9 16	9 28	9 39	9 48	9 56	10 1	10 5	10 5	10 1	9 55	9 46	9 36	9 23	9 6
2 0	8 54	9 9	9 21	9 32	9 41	9 49	9 54	9 58	9 58	9 54	9 48	9 39	9 29	9 16	8 59
2 30	8 49	9 4	9 16	9 27	9 36	9 44	9 49	9 53	9 53	9 49	9 43	9 34	9 24	9 11	8 54
3 0	8 48	9 3	9 15	9 26	9 35	9 43	9 48	9 52	9 52	9 48	9 42	9 33	9 23	9 10	8 53
3 30	8 48	9 3	9 15	9 26	9 35	9 43	9 48	9 52	9 52	9 48	9 42	9 33	9 23	9 10	8 53
4 0	8 52	9 7	9 19	9 30	9 39	9 47	9 52	9 56	9 56	9 52	9 46	9 37	9 27	9 14	8 57
4 30	8 56	9 11	9 23	9 34	9 43	9 51	9 56	10 0	10 0	9 56	9 50	9 41	9 31	9 18	9 1
5 0	9 15	9 30	9 42	9 53	10 2	10 10	10 15	10 19	10 19	10 15	10 9	10 0	9 50	9 37	9 20
5 30	9 37	9 52	10 4	10 15	10 24	10 32	10 37	10 41	10 41	10 37	10 31	10 22	10 12	9 59	9 42
6 0	9 55	10 10	10 22	10 33	10 42	10 50	10 55	10 59	10 59	10 55	10 49	10 40	10 30	10 17	10 0
6 30	10 12	10 27	10 39	10 50	10 59	11 7	11 12	10 16	10 16	11 12	11 6	10 57	10 47	10 34	10 17
7 0	10 18	10 33	10 45	10 56	11 5	11 13	11 18	11 22	11 22	11 18	11 12	[illegible] 3	10 53	10 40	10 23
7 30	10 20	10 35	10 47	10 58	11 7	11 15	11 20	11 24	11 24	11 20	11 14	11 5	10 55	10 42	10 25
8 0	10 22	10 37	10 49	11 0	11 9	11 17	11 22	11 26	11 26	11 22	11 16	11 7	10 57	10 44	10 27
8 30	10 24	10 39	10 51	11 2	11 11	11 19	11 24	11 28	11 28	11 24	11 18	11 9	10 59	10 46	10 29
9 0	10 18	10 33	10 45	10 56	11 5	11 13	11 18	11 22	11 22	11 18	11 12	11 3	10 53	10 40	10 23
9 30	10 10	10 25	10 37	10 48	10 57	11 5	11 10	11 14	11 14	11 10	11 4	10 55	10 45	10 32	10 15
10 0	10 0	10 15	10 27	10 38	10 47	10 55	11 0	11 4	11 4	11 0	10 54	10 45	10 35	10 22	10 5
10 30	9 53	10 8	10 20	10 31	10 40	10 48	10 53	10 57	10 57	10 53	10 47	10 38	10 28	10 15	9 58
11 0	9 45	10 0	10 12	10 23	10 32	10 40	10 45	10 49	10 49	10 45	10 39	10 30	10 20	10 7	9 50
11 30	9 36	9 51	10 3	10 14	10 23	10 31	10 36	10 40	10 40	10 36	10 30	10 21	10 11	9 58	9 41

TABLE V.—SAN DIEGO.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0 0	9 30	9 16	9 4	8 53	8 44	8 36	8 31	8 27	8 27	8 31	8 37	8 46	8 56	9 9	9 26
0 30	9 21	9 6	8 54	8 43	8 34	8 26	8 21	8 17	8 17	8 21	8 27	8 36	8 46	8 59	9 16
1 0	9 14	8 59	8 47	8 36	8 27	8 19	8 14	8 10	8 10	8 14	8 20	8 29	8 39	8 52	9 9
1 30	9 7	8 52	8 40	8 29	8 20	8 12	8 7	8 3	8 3	8 7	8 13	8 22	8 32	8 45	9 2
2 0	0	8 45	8 33	8 22	8 13	8 5	8 0	7 56	7 56	8 0	8 6	8 15	8 25	8 38	8 55
2 30	8 55	8 40	8 28	8 17	8 8	8 0	7 55	7 51	7 51	7 55	8 1	8 10	8 20	8 33	8 50
3 0	8 54	8 39	8 27	8 16	8 7	7 59	7 54	7 50	7 50	7 54	8 0	8 9	8 19	8 32	8 49
3 30	8 54	8 39	8 27	8 16	8 7	7 59	7 54	7 50	7 50	7 54	8 0	8 9	8 19	8 32	8 49
4 0	8 58	8 43	8 31	8 20	8 11	8 3	7 58	7 54	7 54	7 58	8 4	8 13	8 23	8 36	8 53
4 30	9 2	8 47	8 35	8 24	8 15	8 7	8 2	7 58	7 58	8 2	8 8	8 17	8 27	8 40	8 57
5 0	9 21	9 6	8 54	8 48	8 34	8 26	8 21	8 17	8 17	8 21	8 27	8 36	8 46	8 59	9 16
5 30	9 43	9 28	9 16	9 5	8 56	8 48	8 43	8 39	8 39	8 43	8 49	8 58	9 8	9 21	9 38
6 0	10 1	9 46	9 34	9 23	9 14	9 6	9 1	8 57	8 57	9 1	9 7	9 16	9 26	9 39	9 56
6 30	10 18	10 3	9 51	9 40	9 31	9 23	9 18	9 14	9 14	9 18	9 24	9 33	9 43	9 56	10 13
7 0	10 24	10 9	9 57	9 46	9 37	9 29	9 24	9 20	9 20	9 24	9 30	9 39	9 49	10 2	10 19
7 30	10 26	10 11	9 59	9 48	9 39	9 31	9 26	9 22	9 22	9 26	9 32	9 41	9 51	10 4	10 21
8 0	10 28	10 13	10 1	9 50	9 41	9 33	9 28	9 24	9 24	9 28	9 34	9 43	9 53	10 6	10 23
8 30	10 30	10 15	10 3	9 52	9 43	9 35	9 30	9 26	9 26	9 30	9 36	9 45	9 55	10 8	10 25
9 0	10 24	10 9	9 57	9 46	9 37	9 29	9 24	9 20	9 20	9 24	9 30	9 39	9 49	10 2	10 19
9 30	10 16	10 1	9 49	9 38	9 29	9 21	9 16	9 12	9 12	9 16	9 22	8 31	9 41	9 54	10 11
10 0	10 6	9 51	9 39	9 28	9 19	9 11	9 6	9 2	9 2	9 6	9 12	9 21	9 31	9 44	10 1
10 30	9 59	9 44	9 32	9 21	9 12	9 4	8 59	8 55	8 55	8 59	9 5	9 14	9 24	9 37	9 54
11 0	9 51	9 36	9 24	9 13	9 4	8 56	8 51	8 47	8 47	8 51	8 57	9 6	9 16	9 29	9 46
11 30	9 42	9 27	9 15	9 4	8 55	8 47	8 42	8 38	8 38	8 42	8 48	8 57	9 7	9 20	9 37

TABLE IV.—SAN FRANCISCO.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
h. m	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h m.	h. m.	h. m.	h. m.	h. m.
0 0	11 43	11 59	12 15	12 33	12 50	13 03	13 17	13 20	13 19	13 14	13 07	12 57	12 45	12 32	12 18
0 30	11 37	11 53	12 00	12 27	12 44	12 57	13 11	13 14	13 13	13 08	13 01	12 51	12 39	12 26	12 12
1 0	11 31	11 47	12 03	12 21	12 38	12 51	13 05	13 08	13 07	13 02	12 55	12 45	12 33	12 20	12 06
1 30	11 25	11 41	11 57	12 15	12 32	12 45	12 59	13 02	13 01	12 56	12 49	12 39	12 27	12 14	12 00
2 0	11 19	11 35	11 51	12 09	12 26	12 39	12 53	12 56	12 55	12 50	12 43	12 33	12 21	12 08	11 54
2 30	11 14	11 30	11 46	12 04	12 21	12 34	12 48	12 51	12 50	12 45	12 38	12 28	12 16	12 03	11 49
3 0	11 11	11 27	11 43	12 01	12 18	12 31	12 45	12 48	12 47	12 42	12 35	12 25	12 13	12 00	11 46
3 30	11 11	11 27	11 43	12 01	12 18	12 31	12 45	12 48	12 47	12 42	12 35	12 25	12 13	12 00	11 46
4 0	11 16	11 32	11 48	12 06	12 23	12 36	12 50	12 53	12 52	12 47	12 40	12 30	12 18	12 05	11 51
4 30	11 24	11 40	11 56	12 14	12 31	12 44	12 58	13 01	13 00	12 55	12 48	12 38	12 26	13 13	11 59
5 0	11 33	11 49	12 05	12 23	12 40	12 53	13 07	13 10	13 09	13 04	12 57	12 47	12 35	12 22	12 08
5 30	11 41	11 57	12 13	12 31	12 48	13 01	13 15	13 18	13 17	13 12	13 05	12 55	12 43	12 30	12 16
6 0	11 49	12 05	12 21	12 39	12 56	13 09	13 23	13 26	13 25	13 20	13 13	13 03	12 51	12 38	12 24
6 30	11 54	12 10	12 26	12 44	13 01	13 14	13 28	13 31	13 30	13 25	13 18	13 08	12 56	12 43	12 29
7 0	12 01	12 17	12 33	12 51	13 08	13 21	13 35	13 38	13 37	13 32	13 25	13 15	13 03	12 50	12 36
7 30	12 07	12 23	12 39	12 57	13 14	13 27	13 41	13 44	13 43	13 38	13 31	13 21	13 09	12 56	12 42
8 0	12 12	12 28	12 44	13 02	13 19	13 32	13 46	13 49	13 48	13 43	13 36	13 26	13 14	13 01	12 47
8 30	12 15	12 31	12 47	13 05	13 22	13 35	13 49	13 52	13 51	13 46	13 39	13 29	13 17	13 04	12 50
9 0	12 14	12 30	12 46	13 04	13 21	13 34	13 48	13 57	13 50	13 45	13 38	13 28	13 16	13 03	12 49
9 30	12 12	12 28	12 44	13 02	13 19	13 32	13 46	13 49	13 48	13 43	13 36	13 26	13 14	13 01	12 47
10 0	12 08	12 24	12 40	12 58	13 15	13 28	13 42	13 45	13 44	13 39	13 32	13 22	13 10	12 57	12 43
10 30	12 02	12 18	12 34	12 52	13 09	13 22	13 36	13 39	13 38	13 33	13 26	13 16	13 04	12 51	12 37
11 0	11 55	12 11	12 27	12 45	13 02	13 15	13 29	13 32	13 31	13 26	13 19	13 09	12 57	12 44	12 30
11 30	11 47	12 03	12 19	12 37	12 54	13 07	13 21	13 24	12 23	13 18	13 11	13 01	12 49	12 36	12 22

TABLE V.—SAN FRANCISCO.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0 0	12 27	12 11	11 55	11 37	11 20	11 07	10 53	10 50	10 51	10 56	11 03	11 13	11 25	11 38	11 52
0 30	12 21	12 05	11 49	11 31	11 14	11 01	10 47	10 44	10 45	10 50	10 57	11 07	11 19	11 32	11 46
1 0	12 15	11 59	11 43	11 25	11 08	10 55	10 41	10 38	10 39	10 44	10 51	11 01	11 13	11 26	11 40
1 30	12 09	11 53	11 37	11 19	11 02	10 49	10 35	10 32	10 33	10 38	10 45	10 55	11 07	11 20	11 34
2 0	12 03	11 47	11 31	11 13	10 56	10 43	10 29	10 26	10 27	10 32	10 39	10 49	11 01	11 14	11 28
2 30	11 58	11 42	11 26	11 08	10 51	10 38	10 24	10 21	10 22	10 27	10 34	10 44	10 56	11 09	11 23
3 0	11 55	11 39	11 23	11 05	10 48	10 35	10 21	10 18	10 19	10 24	10 31	10 41	10 53	11 06	11 20
3 30	11 55	11 39	11 23	11 05	10 48	10 35	10 21	10 18	10 19	10 24	10 31	10 41	10 53	11 06	11 20
4 0	12 00	11 44	11 28	11 10	10 53	10 40	10 26	10 23	10 24	10 29	10 36	10 46	10 58	11 11	11 25
4 30	12 08	11 52	11 36	11 18	11 01	10 48	10 34	10 31	10 32	10 37	10 44	10 54	11 06	11 19	11 33
5 0	12 17	12 01	11 45	11 27	11 10	10 57	10 43	10 40	10 41	10 46	10 53	11 03	11 15	11 28	11 42
5 30	12 25	12 09	11 53	11 35	11 18	11 05	10 51	10 48	10 49	10 54	11 01	11 11	11 23	11 36	11 50
6 0	12 33	12 17	12 01	11 43	11 26	11 13	10 59	10 56	10 57	11 02	11 09	11 19	11 31	11 44	11 58
6 30	12 38	12 22	12 06	11 48	11 31	11 18	11 04	11 01	11 02	11 07	11 14	11 24	11 36	11 49	12 03
7 0	12 45	12 29	12 13	11 55	11 38	11 25	11 11	11 08	11 09	11 14	11 21	11 31	11 43	11 56	12 10
7 30	12 51	12 35	12 19	12 01	11 44	11 31	11 17	11 14	11 15	11 20	11 27	11 37	11 49	12 02	12 16
8 0	12 56	12 40	12 24	12 06	11 49	11 36	11 22	11 19	11 20	11 25	11 32	11 42	11 54	12 07	12 21
8 30	12 59	12 43	12 27	12 09	11 52	11 39	11 25	11 22	11 23	11 28	11 35	11 45	11 57	12 10	12 24
9 0	12 58	12 42	12 26	12 08	11 51	11 38	11 24	11 21	11 22	11 27	11 34	11 44	11 56	12 09	12 23
9 30	12 56	12 40	12 24	12 06	11 49	11 36	11 22	11 19	11 20	11 25	11 32	11 42	11 54	12 07	12 21
10 0	12 52	12 36	12 20	12 02	11 45	11 32	11 18	11 15	11 16	11 21	11 28	11 38	11 50	12 03	12 17
10 30	12 46	12 30	12 14	11 56	11 39	11 26	11 12	11 09	11 10	11 15	11 22	11 32	11 44	11 57	12 11
11 0	12 39	12 23	12 07	11 49	11 32	11 19	11 05	11 02	11 03	11 08	11 15	11 25	11 37	11 50	12 04
11 30	12 31	12 15	11 59	11 41	11 24	11 11	10 57	10 54	10 55	11 00	11 07	11 17	11 29	11 42	11 56

TABLE IV.—ASTORIA.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0 0	12 42	12 55	13 5	13 18	13 28	13 38	13 41	13 45	13 46	13 44	13 40	13 34	13 24	13 14	13 2
0 30	12 36	12 49	12 59	13 12	13 22	13 32	13 35	13 39	13 40	13 38	13 34	13 28	13 18	13 8	12 56
1 0	12 29	12 42	12 52	13 5	13 15	13 25	13 28	13 32	13 33	13 31	13 27	13 21	13 11	13 1	12 49
1 30	12 23	12 36	12 46	12 59	13 9	13 19	13 22	13 26	13 27	13 25	13 21	13 15	13 5	12 55	12 43
2 0	12 15	12 28	12 38	12 51	13 1	13 11	13 14	13 18	13 19	13 17	13 13	13 7	12 57	12 47	12 35
2 30	12 9	12 22	12 32	12 45	12 55	13 5	13 8	13 12	13 13	13 11	13 7	13 1	12 51	12 41	12 29
3 0	12 3	12 16	12 26	12 39	12 49	12 59	13 2	13 6	13 7	13 5	13 1	12 55	12 45	12 35	12 23
3 30	11 58	12 11	12 21	12 34	12 44	12 54	12 57	13 1	13 2	13 0	12 56	12 50	12 40	12 30	12 18
4 0	11 57	12 10	12 20	12 33	12 43	12 53	12 56	13 0	13 1	12 59	12 55	12 49	12 39	12 29	12 17
4 30	12 0	12 13	12 23	12 36	12 46	12 56	12 59	13 3	13 4	13 2	12 58	12 52	12 42	12 32	12 20
5 0	12 8	12 21	12 31	12 44	12 54	13 4	13 7	13 11	13 12	13 10	13 6	13 0	12 50	12 40	12 28
5 30	12 15	12 28	12 38	12 51	13 1	13 11	13 14	13 18	13 19	13 17	13 13	13 7	12 57	12 47	12 35
6 0	12 25	12 38	12 48	13 1	13 11	13 21	13 24	13 28	13 29	13 27	13 23	13 17	13 7	12 57	12 45
6 30	12 36	12 49	12 59	13 12	13 22	13 32	13 35	13 39	13 40	13 38	13 34	13 28	13 18	13 8	12 56
7 0	12 45	12 58	13 8	13 21	13 31	13 41	13 44	13 48	13 49	13 47	13 43	13 37	13 27	13 17	13 5
7 30	12 55	13 8	13 18	13 31	13 41	13 51	13 54	13 58	13 59	13 57	13 53	13 47	13 37	13 27	13 15
8 0	13 3	13 16	13 26	13 39	13 49	13 59	14 2	14 6	14 7	14 5	14 1	13 55	13 45	13 35	13 23
8 30	13 8	13 21	13 31	13 44	13 54	14 4	14 7	14 11	14 12	14 10	14 6	14 0	13 50	13 40	13 28
9 0	13 10	13 23	13 33	13 46	13 56	14 6	14 9	14 13	14 14	14 12	14 8	14 2	13 52	13 42	13 30
9 30	13 9	13 22	13 32	13 45	13 55	14 5	14 8	14 12	14 13	14 11	14 7	14 1	13 51	13 41	13 29
10 0	13 5	13 18	13 28	13 41	13 51	14 1	14 4	14 8	14 9	14 7	14 3	13 57	13 47	13 37	13 25
10 30	12 59	13 12	13 22	13 35	13 45	13 55	13 58	14 2	14 3	14 1	13 57	13 51	13 41	13 31	13 19
11 0	12 53	13 6	13 16	13 29	13 39	13 49	13 52	13 56	13 57	13 55	13 51	13 45	13 35	13 25	15 13
11 30	12 46	12 59	13 9	13 22	13 32	13 42	13 45	13 49	13 50	13 48	13 44	13 38	13 26	13 18	13 6

TABLE V.—ASTORIA.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0 0	13 10	12 57	12 47	12 34	12 24	12 14	12 11	12 7	12 6	12 8	12 12	12 18	12 28	12 38	12 50
0 30	13 4	12 51	12 41	12 28	12 18	12 8	12 5	12 1	12 0	12 2	12 6	12 12	12 22	12 32	12 44
1 0	12 57	12 44	12 34	12 21	12 11	12 1	11 58	11 54	11 53	11 55	11 59	12 5	12 15	12 25	12 37
1 30	12 51	12 38	12 28	12 15	12 5	11 55	11 52	11 48	11 47	11 49	11 53	11 59	12 9	12 19	12 31
2 0	12 43	12 30	12 20	12 7	11 57	11 47	11 44	11 40	11 39	11 41	11 45	11 51	12 1	12 11	12 23
2 30	12 37	12 24	12 14	12 1	11 51	11 41	11 38	11 34	11 33	11 35	11 39	11 45	11 55	12 5	12 17
3 0	12 31	12 18	12 8	11 55	11 45	11 35	11 32	11 28	11 27	11 29	11 33	11 39	11 49	11 59	12 11
3 30	12 26	12 13	12 3	11 50	11 40	11 30	11 27	11 23	11 22	11 24	11 28	11 34	11 44	11 54	12 6
4 0	12 25	12 12	12 2	11 49	11 39	11 29	11 26	11 22	11 21	11 23	11 27	11 33	11 43	11 53	12 5
4 30	12 28	12 15	12 5	11 52	11 42	11 32	11 29	11 25	11 24	11 26	11 30	11 36	11 46	11 56	12 8
5 0	12 36	12 23	12 13	12 0	11 50	11 40	11 37	11 33	11 32	11 34	11 38	11 44	11 54	12 4	12 16
5 30	12 43	12 30	12 20	12 7	11 57	11 47	11 44	11 40	11 39	11 41	11 45	11 51	12 1	12 11	12 23
6 0	12 53	12 40	12 30	12 17	12 7	11 57	11 54	11 50	11 49	11 51	11 55	12 1	12 11	12 21	12 33
6 30	13 4	12 51	12 41	12 28	12 18	12 8	12 5	12 1	12 0	12 2	12 6	12 12	12 22	12 32	12 44
7 0	13 13	13 0	12 50	12 37	12 27	12 17	12 14	12 10	12 9	12 11	12 15	12 21	12 31	12 41	12 53
7 30	13 23	13 10	13 0	12 47	12 37	12 27	12 24	12 20	12 19	12 21	12 25	12 31	12 41	12 51	13 3
8 0	13 31	13 18	13 8	12 55	12 45	12 35	12 32	12 28	12 27	12 29	12 33	12 39	12 49	12 59	13 11
8 30	13 36	13 23	13 13	13 0	12 50	12 40	12 37	12 33	12 32	12 34	12 38	12 44	12 54	13 4	13 16
9 0	13 38	13 25	13 15	13 2	12 52	12 42	12 39	12 35	12 34	12 36	12 40	12 46	12 56	13 6	13 18
9 30	13 37	13 24	13 14	13 1	12 51	12 41	12 38	12 34	12 33	12 35	12 39	12 45	12 55	13 5	13 17
10 0	13 33	13 20	13 10	12 57	12 47	12 37	12 34	12 30	12 29	12 31	12 35	12 41	12 51	13 1	13 13
10 30	13 27	13 14	13 4	12 51	12 41	12 31	12 28	12 24	12 23	12 25	12 29	12 35	12 45	12 55	13 7
11 0	13 21	13 8	12 58	12 45	12 35	12 25	12 22	12 18	12 17	12 19	12 23	12 29	12 39	12 49	13 1
11 30	13 14	13 1	12 51	12 38	12 28	12 18	12 15	12 11	12 10	12 12	12 16	12 22	12 32	12 42	12 54

TABLE IV.—PORT TOWNSHEND.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION. Before— 7	6	5	4	3	2	1	• 0	After— 1	2	3	4	3	6	7
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m	h. m.	h. m.	h. m	h. m.	h. m.	h. m.	h. m.
0 0	3 45	3 21	2 51	2 2	1 32	1 13	1 26	1 44	2 2	2 21	2 42	2 57	3 15	3 33	3 45
0 30	3 38	2 14	2 44	1 55	1 25	1 6	1 19	1 37	1 55	2 14	2 35	2 50	3 8	3 26	3 38
1 0	3 32	3 8	2 38	1 49	1 19	1 0	1 13	1 31	1 49	2 8	2 29	2 44	3 2	3 20	3 32
1 30	3 26	3 2	2 32	1 43	1 13	0 54	1 7	1 25	1 43	2 2	2 23	2 38	2 56	3 14	3 26
2 0	3 21	2 57	2 27	1 38	1 8	0 49	1 2	1 20	1 38	1 57	2 18	2 33	2 51	3 9	3 21
2 30	3 18	2 54	2 24	1 35	1 5	0 46	0 59	1 17	1 35	1 54	2 15	2 20	2 48	3 6	3 18
3 0	3 16	2 52	2 22	1 33	1 3	0 44	0 57	1 15	1 33	1 52	2 13	2 28	2 46	3 4	3 16
3 30	3 17	2 53	2 23	1 34	1 4	0 45	0 58	1 16	1 34	1 53	2 14	2 29	2 47	3 5	3 17
4 0	3 21	2 57	2 27	1 38	1 8	0 49	1 2	1 20	1 38	1 57	2 18	2 33	2 51	3 9	3 21
4 30	3 26	3 2	2 32	1 43	1 13	0 54	1 7	1 25	1 43	2 2	2 23	2 38	2 56	3 14	3 26
5 0	3 32	3 8	2 38	1 49	1 19	1 0	1 13	1 31	1 49	2 8	2 29	2 44	3 2	3 20	3 32
5 30	3 41	3 17	2 47	1 58	1 28	1 9	1 22	1 40	1 58	2 17	2 38	2 53	3 11	3 29	3 41
6 0	3 52	3 28	2 58	2 9	1 39	1 20	1 33	1 51	2 9	2 28	2 49	3 4	3 22	3 40	3 52
6 30	4 1	3 37	3 7	2 18	1 48	1 29	1 42	2 0	2 18	2 37	2 58	3 13	3 31	3 49	4 1
7 0	4 8	3 44	3 14	2 25	1 55	1 36	1 49	2 7	2 25	2 44	3 5	3 20	3 38	3 56	4 8
7 30	4 15	3 51	3 21	2 32	2 2	1 43	1 56	2 14	2 32	2 51	3 12	3 27	3 45	4 3	4 15
8 0	4 18	3 54	3 24	2 35	2 5	1 46	1 59	2 17	2 35	2 54	3 15	3 30	3 48	4 6	4 18
8 30	4 19	3 55	3 25	2 36	2 6	1 47	2 0	2 18	2 36	2 55	3 16	3 31	3 49	4 7	4 19
9 0	4 18	3 54	3 24	2 35	2 5	1 46	1 59	2 17	2 35	2 54	3 15	3 30	3 48	4 6	4 18
9 30	4 15	3 51	3 21	2 32	2 2	1 43	1 56	2 14	2 32	2 51	3 12	3 27	3 45	4 3	4 15
10 0	4 10	3 46	3 16	2 27	1 57	1 38	1 51	2 9	2 27	2 46	3 7	3 22	3 40	3 58	4 10
10 30	4 6	3 42	3 12	2 23	1 53	1 34	1 47	2 5	2 23	2 42	3 3	3 18	3 36	3 54	4 6
11 0	4 0	3 36	3 6	2 17	1 47	1 28	1 41	1 59	2 17	2 36	2 57	3 12	3 30	3 48	4 0
11 30	3 54	3 30	3 0	2 11	1 41	1 22	1 35	1 53	2 11	2 30	2 51	3 6	3 24	3 42	3 54

TABLE V.—PORT TOWNSHEND.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION. Before— 7	6	5	4	3	2	1	0	After— 1	2	3	4	5	6	7
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0 0	3 45	4 9	4 39	5 28	5 58	6 17	6 4	5 46	5 28	5 9	4 48	4 33	4 15	3 57	3 45
0 30	3 38	4 2	4 32	5 21	5 51	6 10	5 57	5 39	5 21	5 2	4 41	4 26	4 8	3 50	3 38
1 0	3 32	3 56	4 26	5 15	5 45	6 4	5 51	5 33	5 15	4 56	4 35	4 20	4 2	3 44	3 32
1 30	3 26	3 50	4 20	5 9	5 39	5 58	5 45	5 27	5 9	4 50	4 29	4 14	3 56	3 38	3 26
2 0	3 21	3 45	4 15	5 4	5 34	5 53	5 40	5 22	5 4	4 45	4 24	4 9	3 51	3 33	3 21
2 30	3 18	3 42	4 12	5 1	5 31	5 50	5 37	5 19	5 1	4 42	4 21	4 6	3 48	3 30	3 18
3 0	3 16	3 40	4 10	4 59	5 29	5 48	5 35	5 17	4 59	4 40	4 19	4 4	3 46	3 28	3 16
3 30	3 17	3 41	4 11	5 0	5 30	5 49	5 36	5 18	5 0	4 41	4 20	4 5	3 47	3 29	3 17
4 0	3 21	3 45	4 15	5 4	5 34	5 53	5 40	5 22	5 4	5 45	4 24	4 9	3 51	3 33	3 21
4 30	3 26	3 50	4 20	5 9	5 39	5 58	5 45	5 27	5 9	4 50	4 29	4 14	3 56	3 38	3 26
5 0	3 32	3 56	4 26	5 15	5 45	6 4	5 51	5 33	5 15	4 56	4 35	4 20	4 2	3 44	3 32
5 30	3 41	4 5	4 35	5 24	5 54	6 13	6 0	5 42	5 24	5 5	4 44	4 29	4 11	3 53	3 41
6 0	3 52	4 16	4 46	5 35	6 5	6 24	6 11	5 53	5 35	5 16	4 55	4 40	4 22	4 4	3 52
6 30	4 1	4 25	4 55	5 44	6 14	6 33	6 20	6 2	5 44	5 25	5 4	4 49	4 31	4 13	4 1
7 0	4 8	4 32	5 2	5 51	6 21	6 40	6 27	6 9	5 51	5 32	5 11	4 56	4 38	4 20	4 8
7 30	4 15	4 39	5 9	5 58	6 28	6 47	6 34	6 16	5 58	5 39	5 18	5 3	4 45	4 27	4 15
8 0	4 18	4 42	5 12	6 1	6 31	6 50	6 37	6 19	6 1	5 42	5 21	5 6	4 48	4 30	4 18
8 30	4 19	4 43	5 13	6 2	6 32	6 51	6 38	6 20	6 2	5 43	5 22	5 7	4 49	4 31	4 19
9 0	4 18	4 42	5 12	6 1	6 31	6 50	6 37	6 19	6 1	5 42	5 21	5 6	4 48	4 30	4 18
9 30	4 15	4 39	5 9	5 58	6 28	6 47	6 34	6 16	5 58	5 39	5 18	5 3	4 45	4 27	4 15
10 0	4 10	4 34	5 4	5 53	6 23	6 42	6 29	6 11	5 53	5 34	5 13	4 58	4 40	4 22	4 10
10 30	4 6	4 30	5 0	5 49	6 19	6 38	6 25	6 7	5 49	5 30	5 9	4 54	4 36	4 18	4 6
11 0	4 0	4 24	4 54	5 43	6 13	6 32	6 19	6 1	5 43	5 24	5 3	4 48	4 30	4 12	4 0
11 30	3 54	4 18	4 48	5 37	6 7	6 26	6 13	5 55	5 37	5 18	4 57	4 42	4 24	4 6	3 54

If we disregard the daily inequality, the column headed San Francisco in Table II would give us, as in the examples on the Atlantic coast, the means of determining the time of high water.

Example V.—Required the time of high water at North Beach, San Francisco, Cal., on the 7th of February, 1853.

1st. The time of the moon's transit at Greenwich, from the Nautical Almanac, is 11*h.* 41*m.*; the longitude of San Francisco 8*h.* 10*m.*, requiring a correction of 16*m.* to the time of transit for San Francisco, which is thus found to be 11*h.* 57*m.*

2d. The moon's declination is south, and at the time of transit about two days after the greatest. Entering Table IV, we find 12*h.* (or 0*h.*) of transit, the nearest number to 11*h.* 57*m.* which the table gives; and following the line horizontally, until we come to two days after the greatest declination, we find 13*h.* 14*m.*

To 11*h.* 57*m.*, time of transit of the moon, February 7, San Francisco, add 13*h.* 14*m.*, from column 0*h.*, transit, and two days after greatest declination; the sum, 25*h.* 11*m.*, or 1*h.* 11*m.*, February 8, is the time of high water, corresponding to the transit which we took of February 7. If we desire the tide of February 7 we must go back to the moon's transit of the 6th. The example was purposely assumed to show this case.

	11*h.*	01*m.*,	time of transit February 6, 1853.
	13	31	number for 11*h.* transit, and one day from greatest declination.
Sum	24	32	time of high water 0*h.* 32*m.* a. m. February 7.

The height of high water.—The height of high water is obtained in a similar manner by the use of Table VI and Table VII, entering these in the same way with the time of transit and days from the greatest declination. Table VI is for south declination, and Table VII for north.

TABLE VI.—KEY WEST.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	1.5	1.6	1.8	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.8	1.7	1.5
1	1.5	1.6	1 8	1.9	2.0	2.0	2.0	2 0	2.0	2.0	2.0	1.9	1.8	1.7	1.5
2	1.5	1.6	1.8	1.9	2.0	2.0	2.0	2 0	2.0	2.0	2.0	1.9	1.8	1.7	1.5
3	1.4	1.5	1.7	1.8	1.9	1.9	1.9	1.9	1.9	1 9	1.9	1.8	1.7	1.6	1.4
4	1.3	1.4	1 6	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.6	1.5	1.3
5	1.2	1.3	1.5	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.5	1.4	1.2
6	1.1	1.2	1.4	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.4	1.3	1.1
7	1.1	1.2	1.4	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.4	1.3	1.1
8	1.2	1.3	1.5	1.6	1.7	1.7	1.7	1 7	1.7	1.7	1.7	1.6	1.5	1.4	1.2
9	1.3	1.4	1.6	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.6	1.5	1.3
10	1.4	1.5	1.7	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.7	1.6	1.4
11	1.5	1.6	1.8	1.9	2.0	2 0	2.0	2.0	2.0	2.0	2.0	1.9	1.8	1.7	1.5

TABLE VII.—KEY WEST.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0	1.7	1.6	1.4	1.3	1.2	1.1	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.6	1.8
1	1.7	1.6	1.4	1.3	1.2	1.1	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.6	1.8
2	1.7	1.6	1.4	1.3	1.2	1.1	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.6	1.8
3	1.6	1.5	1.3	1.2	1.1	1.0	0.9	0.9	1.0	1.0	1.1	1.2	1.3	1.5	1.7
4	1.5	1.4	1.2	1.1	1.0	0.9	0.8	0.8	0.9	0.9	1.0	1.1	1.2	1.4	1.6
5	1.4	1.3	1.1	1.0	0.9	0.8	0.7	0.7	0.8	0.8	0.9	1.0	1.1	1.3	1.5
6	1.3	1.2	1.0	0.9	0.8	0.7	0.6	0.6	0.7	0.7	0.8	0.9	1.0	1.2	1.4
7	1.3	1.2	1.0	0.9	0.8	0.7	0.6	0.6	0.7	0.7	0.8	0.9	1.0	1.2	1.4
8	1.4	1.3	1.1	1.0	0.9	0.8	0.7	0.7	0.8	0.8	0.9	1.0	1.1	1.3	1.5
9	1.5	1.4	1.2	1.1	1.0	0.9	0.8	0.8	0.9	0.9	1.0	1.1	1.2	1.4	1.6
10	1.6	1.5	1.3	1.2	1.1	1.0	0.9	0.9	1.0	1.0	1.1	1.2	1.3	1.5	1.7
11	1.7	1.6	1.4	1.3	1.2	1.1	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.6	1.8

TABLE VI.—SAN DIEGO.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0	4.7	4.5	4.3	4.2	4.1	4.1	4.1	4.1	4.2	4.3	4.5	4.8	5.1	5.5	5.8
1	4.6	4.4	4.2	4.1	4.0	4.0	4.0	4.0	4.1	4.2	4.4	4.7	5.0	5.4	5.7
2	4.4	4.2	4.0	3.9	3.8	3.8	3.8	3.8	3.9	4.0	4.2	4.5	4.8	5.2	5.5
3	4.1	3.9	3.7	3.6	3.5	3.5	3.5	3.5	3.6	3.7	3.9	4.2	4.5	4.9	5.2
4	3.8	3.6	3.4	3.3	3.2	3.2	3.2	3.2	3.3	3.4	3.6	3.9	4.2	4.6	4.9
5	3.6	3.4	3.2	3.1	3.0	3.0	3.0	3.0	3.1	3.2	3.4	3.7	4.0	4.4	4.7
6	3.6	3.4	3.2	3.1	3.0	3.0	3.0	3.0	3.1	3.2	3.4	3.7	4.0	4.4	4.7
7	3.7	3.5	3.3	3.2	3.1	3.1	3.1	3.1	3.2	3.3	3.5	3.8	4.1	4.5	4.8
8	3.8	3.6	3.4	3.3	3.2	3.2	3.2	3.2	3.3	3.4	3.6	3.9	4.2	4.6	4.9
9	4.4	4.2	4.0	3.9	3.8	3.8	3.8	3.8	3.9	4.0	4.2	4.5	4.8	5.2	5.5
10	4.7	4.5	4.3	4.2	4.1	4.1	4.1	4.1	4.2	4.3	4.5	4.8	5.1	5.5	5.8
11	4.8	4.6	4.4	4.3	4.2	4.2	4.2	4.2	4.3	4.4	4.6	4.9	5.2	5.6	5.9

TABLE VII.—SAN DIEGO.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0	5.7	5.9	6.1	6.2	6.3	6.3	6.3	6.3	6.2	6.1	5.9	5.6	5.3	4.9	4.6
1	5.6	5.8	6.0	6.1	6.2	6.2	6.2	6.2	6.1	6.0	5.8	5.5	5.2	4.8	4.5
2	5.4	5.6	5.8	5.9	6.0	6.0	6.0	6.0	5.9	5.8	5.6	5.3	5.0	4.6	4.3
3	5.1	5.3	5.5	5.6	5.7	5.7	5.7	5.7	5.6	5.5	5.3	5.0	4.7	4.3	4.0
4	4.8	5.0	5.2	5.3	5.4	5.4	5.4	5.4	5.3	5.2	5.0	4.7	4.4	4.0	3.7
5	4.6	4.8	5.0	5.1	5.2	5.2	5.2	5.2	5.1	5.0	4.8	4.5	4.2	3.8	3.5
6	4.6	4.8	5.0	5.1	5.2	5.2	5.2	5.2	5.1	5.0	4.8	4.5	4.2	3.8	3.5
7	4.7	4.9	5.1	5.2	5.3	5.3	5.3	5.3	5.2	5.1	4.9	4.6	4.3	3.9	3.6
8	4.8	5.0	5.2	5.3	5.4	5.4	5.4	5.4	5.3	5.2	5.0	4.7	4.4	4.0	3.7
9	5.4	5.6	5.8	5.9	6.0	6.0	6.0	6.0	5.9	5.8	5.6	5.3	5.0	4.6	4.3
10	5.7	5.9	6.1	6.2	6.3	6.3	6.3	6.3	6.2	6.1	5.9	5.6	5.3	4.9	4.6
11	5.8	6.0	6.2	6.3	6.4	6.4	6.4	6.4	6.3	6.2	6.0	5.7	5.4	5.0	4.7

TABLE VI.—SAN FRANCISCO.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	4.8	4.7	4.5	4.3	4.3	4.2	4.3	4.3	4.4	4.5	4.7	4.8	5.0	5.3	5.5
1	4.7	4.6	4.4	4.2	4.2	4.1	4.2	4.2	4.3	4.4	4.6	4.7	4.9	5.2	5.4
2	4.6	4.5	4.3	4.1	4.1	4.0	4.1	4.1	4.2	4.3	4.5	4.6	4.8	5.1	5.3
3	4.5	4.4	4.2	4.0	4.0	3.9	4.0	4.0	4.1	4.2	4.4	4.5	4.7	5.0	5.2
4	4.3	4.2	4.0	3.8	3.8	3.7	3.8	3.8	3.9	4.0	4.2	4.3	4.5	4.8	5.0
5	4.1	4.0	3.8	3.6	3.6	3.5	3.6	3.6	3.7	3.8	4.0	4.1	4.3	4.6	4.8
6	4.1	4.0	3.8	3.6	3.6	3.5	3.6	3.6	3.7	3.8	4.0	4.1	4.3	4.6	4.8
7	4.2	4.1	3.9	3.7	3.7	3.6	3.7	3.7	3.8	3.9	4.1	4.2	4.4	4.7	4.9
8	4.4	4.3	4.1	3.9	3.9	3.8	3.9	3.9	4.0	4.1	4.3	4.4	4.6	4.9	5.1
9	4.5	4.4	4.2	4.0	4.0	3.9	4.0	4.0	4.1	4.2	4.4	4.5	4.7	5.0	5.2
10	4.7	4.6	4.4	4.2	4.2	4.1	4.2	4.2	4.3	4.4	4.6	4.7	4.9	5.2	5.4
11	4.8	4.7	4.5	4.3	4.3	4.2	4.3	4.3	4.4	4.5	4.7	4.8	5.0	5.3	5.5

TABLE VII.—SAN FRANCISCO.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	5.4	5.5	5.7	5.9	5.9	6.0	5.9	5.9	5.8	5.7	5.5	5.4	5.2	4.9	4.7
1	5.3	5.4	5.6	5.8	5.8	5.9	5.8	5.8	5.7	5.6	5.4	5.3	5.1	4.8	4.6
2	5.2	5.3	5.5	5.7	5.7	5.8	5.7	5.7	5.6	5.5	5.3	5.2	5.0	4.7	4.5
3	5.1	5.2	5.4	5.6	5.6	5.7	5.6	5.6	5.5	5.4	5.2	5.1	4.9	4.6	4.4
4	4.9	5.0	5.2	5.4	5.4	5.5	5.4	5.4	5.3	5.2	5.0	4.9	4.7	4.4	4.2
5	4.7	4.8	5.0	5.2	5.2	5.3	5.2	5.2	5.1	5.0	4.8	4.7	4.5	4.2	4.0
6	4.7	4.8	5.0	5.2	5.2	5.3	5.2	5.2	5.1	5.0	4.8	4.7	4.5	4.2	4.0
7	4.8	4.9	5.1	5.3	5.3	5.4	5.3	5.3	5.2	5.1	4.9	4.8	4.6	4.3	4.1
8	5.0	5.1	5.3	5.5	5.5	5.6	5.5	5.5	5.4	5.3	5.1	5.0	4.8	4.5	4.3
9	5.1	5.2	5.4	5.6	5.6	5.7	5.6	5.6	5.5	5.4	5.2	5.1	4.9	4.6	4.4
10	5.3	5.4	5.6	5.8	5.8	5.9	5.8	5.8	5.7	5.6	5.4	5.3	5.1	4.8	4.6
11	5.4	5.5	5.7	5.9	5.9	6.0	5.9	5.9	5.8	5.7	5.5	5.4	5.2	4.9	4.7

TABLE VI.—ASTORIA.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	8.0	8.3	8.4	8.5	8.6	8.6	8.6	8.6	8.5	8.4	8.3	8.1	7.7	7.4	7.0
1	8.0	8.2	8.4	8.5	8.6	8.6	8.6	8.6	8.5	8.4	8.2	8.1	7.7	7.4	7.0
2	7.8	8.1	8.2	8.4	8.4	8.4	8.4	8.4	8.3	8.2	8.1	7.9	7.5	7.2	6.8
3	7.5	7.8	7.9	8.1	8.1	8.1	8.1	8.1	8.0	7.9	7.8	7.6	7.2	6.9	6.5
4	7.1	7.6	7.5	7.7	7.7	7.7	7.7	7.7	7.6	7.5	7.4	7.2	6.8	6.5	6.1
5	6.7	7.0	7.2	7.3	7.3	7.3	7.3	7.3	7.2	7.1	7.0	6.8	6.5	6.1	5.7
6	6.5	6.8	7.0	7.1	7.1	7.1	7.1	7.1	7.0	6.9	6.8	6.6	6.3	5.9	5.5
7	6.7	7.0	7.1	7.2	7.3	7.3	7.3	7.3	7.2	7.1	7.0	6.8	6.4	6.1	5.7
8	7.0	7.3	7.5	7.6	7.6	7.6	7.6	7.6	7.5	7.4	7.3	7.1	6.8	6.4	6.0
9	7.5	7.8	8.0	8.1	8.1	8.1	8.1	8.1	8.0	7.9	7.8	7.6	7.3	6.9	6.5
10	7.9	8.2	8.4	8.5	8.5	8.5	8.5	8.5	8.4	8.3	8.2	8.0	7.7	7.3	6.9
11	8.1	8.4	8.6	8.7	8.7	8.7	8.7	8.7	8.6	8.5	8.4	8.2	7.9	7.5	7.1

TABLE VII.—ASTORIA.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	7.4	7.1	6.9	6.8	6.8	6.8	6.8	6.8	6.9	7.0	7.1	7.3	7.6	8.0	8.4
1	7.4	7.1	6.9	6.8	6.8	6.8	6.8	6.8	6.9	7.0	7.1	7.3	7.6	8.0	8.4
2	7.2	6.9	6.8	6.6	6.6	6.6	6.6	6.6	6.7	6.8	6.9	7.1	7.5	7.8	8.2
3	6.9	6.6	6.5	6.3	6.3	6.3	6.3	6.3	6.4	6.5	6.6	6.8	7.2	7.5	7.9
4	6.5	6.2	6.1	5.9	5.9	5.9	5.9	5.9	6.0	6.1	6.2	6.4	6.7	7.1	7.5
5	6.1	5.9	5.7	5.6	5.5	5.5	5.6	5.6	5.7	5.7	5.9	6.0	6.4	6.7	7.1
6	5.9	5.7	5.5	5.4	5.3	5.3	5.3	5.4	5.5	5.5	5.7	5.9	6.2	6.5	6.9
7	6.1	5.8	5.6	5.5	5.5	5.5	5.5	5.5	5.6	5.7	5.8	6.0	6.3	6.7	7.1
8	6.4	6.2	6.0	5.9	5.8	5.8	5.8	5.8	5.9	6.0	6.2	6.3	6.7	7.0	7.4
9	6.9	6.7	6.5	6.4	6.3	6.3	6.3	6.4	6.4	6.5	6.7	6.8	7.2	7.5	7.9
10	7.3	7.1	6.9	6.8	6.7	6.7	6.7	6.8	6.9	6.9	7.0	7.2	7.6	7.9	8.3
11	7.5	7.2	7.1	7.0	6.9	6.9	6.9	6.9	7.0	7.1	7.2	7.4	7.8	8.1	8.5

TABLE VI.—PORT TOWNSHEND.

Time of moon's transit.	NORTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	6.6	6.3	5.9	6.1	6.4	6.9	7.2	7.4	7.5	7.5	7.5	7.5	7.6	7.7	7.9
1	6.7	6.4	6.0	6.2	6.5	7.0	7.3	7.5	7.6	7.6	7.6	7.6	7.7	7.8	8.0
2	6.6	6.3	5.9	6.1	6.4	6.9	7.2	7.4	7.5	7.5	7.5	7.5	7.6	7.7	7.9
3	6.3	6.0	5.6	5.8	6.1	6.6	6.9	7.1	7.2	7.2	7.2	7.4	7.3	7.4	7.6
4	6.0	5.7	5.3	5.5	5.8	6.3	6.6	6.8	6.9	6.9	6.9	6.9	7.0	7.1	7.3
5	5.9	5.6	5.2	5.4	5.7	6.2	6.5	6.7	6.8	6.8	6.8	6.8	6.9	7.0	7.2
6	6.1	5.8	5.4	5.6	5.9	6.4	6.7	6.9	7.0	7.0	7.0	7.0	7.1	7.2	7.4
7	6.4	6.1	5.7	5.9	6.2	6.7	7.0	7.2	7.3	7.3	7.3	7.3	7.4	7.5	7.7
8	6.5	6.2	5.8	6.0	6.3	6.8	7.1	7.3	7.4	7.4	7.4	7.4	7.5	7.6	7.8
9	6.5	6.2	5.8	6.0	6.3	6.8	7.1	7.3	7.4	7.4	7.4	7.4	7.5	7.6	7.8
10	6.6	6.3	5.9	6.1	6.4	6.9	7.2	7.4	7.5	7.5	7.5	7.5	7.6	7.7	7.9
11	6.6	6.3	5.9	6.1	6.4	6.9	7.2	7.4	7.5	7.5	7.5	7.5	7.6	7.7	7.9

TABLE VII.—PORT TOWNSHEND.

Time of moon's transit.	SOUTH DECLINATION.—DAYS FROM MOON'S GREATEST DECLINATION.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
Hour.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	7.6	7.9	8.3	8.1	7.8	7.3	7.0	6.8	6.7	6.7	6.7	6.7	6.6	6.5	6.3
1	7.7	8.0	8.4	8.2	7.9	7.4	7.1	6.9	6.8	6.8	6.8	6.8	6.7	6.6	6.4
2	7.6	7.9	8.3	8.1	7.8	7.3	7.0	6.8	6.7	6.7	6.7	6.7	6.6	6.5	6.3
3	7.3	7.6	8.0	7.8	7.5	7.0	6.7	6.5	6.4	6.4	6.4	6.4	6.3	6.2	6.0
4	7.0	7.3	7.7	7.5	7.2	6.7	6.4	6.2	6.1	6.1	6.1	6.1	6.0	5.9	5.7
5	6.9	7.2	7.6	7.4	7.1	6.6	6.3	6.1	6.0	6.0	6.0	6.0	5.9	5.8	5.6
6	7.1	7.4	7.8	7.6	7.3	6.8	6.5	6.3	6.2	6.2	6.2	6.2	6.1	6.0	5.8
7	7.4	7.7	8.1	7.9	7.6	7.1	6.8	6.6	6.5	6.5	6.5	6.5	6.4	6.3	6.1
8	7.5	7.8	8.2	8.0	7.7	7.2	6.9	6.7	6.6	6.6	6.6	6.6	6.5	6.4	6.2
9	7.5	7.8	8.2	8.0	7.7	7.2	6.9	6.7	6.6	6.6	6.6	6.6	6.5	6.4	6.2
10	7.6	7.9	8.3	8.1	7.8	7.3	7.0	6.8	6.7	6.7	6.7	6.7	6.6	6.5	6.3
11	7.6	7.9	8.3	8.1	7.8	7.3	7.0	6.8	6.7	6.7	6.7	6.7	6.6	6.5	6.3

Note.—To use these tables with a chart on which the soundings are referred to mean low water, subtract 1.2 foot from the numbers in the tables from San Diego to Astoria, 1.7 foot for Nee-ah harbor, 2.3 for Port Townshend, and 2.7 for Semiahmoo and Steilacoom.

Example VI.—In Example V, to obtain the height of tide on February 7, the declination being south, we enter Table VI for San Francisco, with 0*h.* of transit, and two days after greatest declination, and find that the tide will be 4.5 feet above the mean of the lowest low water, or that 4.5 feet are to be added to the soundings of a chart reduced to the mean of the lowest low waters of each day. If the soundings of the chart are given for mean low water, then 1.2 feet ought to be subtracted from the Tables VI and VII; thus, in this example it would be 3.3 feet.

The approximate time of the successive low and high waters of the day will be found by adding the numbers in Table VIII to the time of the first high water already determined. The table gives the numbers for the different days from the greatest declination.

Tables containing numbers to be added to the time of high water found from Tables IV and V, to obtain the successive high and low waters.

TABLE VIII.—KEY WEST.

Days from moon's greatest declination.	South declination. Low water. (Large.)	South declination. High water. (Small.)	South declination. Low water. (Small.)	North declination. Low water. (Small.)	North declination. High water. (Large.)	North declination. Low water. (Large.)	Days from moon's greatest declination.
	h. m.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	
Before. 7	5 22	12 10	17 38	5 36	12 33	17 46	7 Before.
6	5 42	12 31	17 40	5 18	12 18	17 50	6
5	6 05	12 55	17 41	4 58	12 03	17 56	5
4	6 24	13 17	17 44	4 35	11 44	17 59	4
3	6 39	13 28	17 39	4 11	11 18	17 58	3
2	7 02	13 52	17 40	3 50	10 58	17 58	2
1	7 13	14 01	17 39	3 39	10 46	17 56	1
0	7 18	14 10	17 42	3 37	10 46	17 59	0
After. 1	7 12	14 10	17 48	3 44	10 46	17 52	1 After.
2	6 57	13 58	17 51	3 57	10 54	17 47	2
3	6 39	13 41	17 53	4 21	11 19	17 48	3
4	6 15	13 18	17 53	4 43	11 38	17 45	4
5	5 57	12 59	17 53	5 09	12 03	17 44	5
6	5 32	12 36	17 54	5 26	12 22	17 46	6
7	5 13	12 16	17 53	5 40	12 36	17 46	7

TABLE VIII.—SAN DIEGO.

Days from moon's greatest declination.	South declination. Low water. (Small.)	South declination. High water. (Large.)	South declination. Low water. (Large.)	North declination. Low water. (Large.)	North declination. High water. (Small.)	North declination. Low water. (Small.)	Days from moon's greatest declination.
	h. m.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	
Before. 7	5 44	12 28	18 44	6 16	12 16	18 00	7 Before.
6	5 18	11 58	18 40	6 42	12 46	18 04	6
5	5 00	11 34	18 34	7 00	13 10	18 10	5
4	4 47	11 12	18 25	7 13	13 32	18 19	4
3	4 34	10 54	18 20	7 26	13 50	18 24	3
2	4 24	10 38	18 14	7 36	14 06	18 30	2
1	4 17	10 28	18 11	7 43	14 16	18 33	1
0	4 12	10 20	18 08	7 48	14 24	18 36	0
After. 1	4 14	10 20	18 06	7 46	14 24	18 38	1 After.
2	4 21	10 28	18 04	7 36	14 16	18 40	2
3	4 38	10 40	18 02	7 22	14 04	18 42	3
4	5 01	10 56	17 57	6 59	13 46	18 47	4
5	5 25	11 18	17 53	6 35	13 26	18 51	5
6	5 49	11 44	17 55	6 11	13 00	18 49	6
7	6 18	12 18	18 00	5 42	12 26	18 44	7

TABLE VIII.—SAN FRANCISCO.

Days from moon's greatest declination.		SOUTH DECLINATION.			NORTH DECLINATION.			Days from moon's greatest declination.	
		Low water. (Small.)	High water. (Large.)	Low water. (Large.)	Low water. (Large.)	High water. (Small.)	Low water. (Small.)		
		h. m.	h. m.	h. m.	h. m.	h. m.	h. m.		
Before.	7	5 58	13 14	18 58	5 44	11 46	17 44	7	Before.
	6	5 36	12 42	18 48	6 06	12 18	17 54	6	
	5	5 14	12 10	18 38	6 28	12 50	18 04	5	
	4	4 55	11 34	18 21	6 47	13 26	18 21	4	
	3	4 37	11 00	18 05	7 05	14 00	18 37	3	
	2	4 24	10 34	17 52	7 18	14 26	18 50	2	
	1	4 12	10 06	17 36	7 30	14 54	19 06	1	
	0	4 12	10 00	17 30	7 30	15 00	19 12	0	
After.	1	4 17	10 02	17 27	7 25	14 58	19 15	1	After.
	2	4 27	10 12	17 27	7 15	14 48	19 15	2	
	3	4 41	10 26	17 27	7 01	14 34	19 15	3	
	4	4 56	10 46	17 32	6 46	14 14	19 10	4	
	5	5 14	11 10	17 38	6 28	13 50	19 04	5	
	6	5 36	11 36	17 42	6 06	13 24	19 00	6	
	7	5 57	12 04	17 49	5 45	12 56	18 53	7	

TABLE VIII.—ASTORIA.

Days from moon's greatest declination.		SOUTH DECLINATION.			NORTH DECLINATION.			Days from moon's greatest declination.	
		Low water. (Small)	High water. (Large.)	Low water. (Large.)	Low water. (Large.)	High water. (Small.)	Low water. (Small.)		
		h. m.	h. m.	h. m.	h. m.	h. m.	h. m.		
Before.	7	6 38	12 59	19 17	6 18	12 03	18 41	7	Before.
	6	6 14	12 33	19 15	6 42	12 29	18 43	6	
	5	5 55	12 13	19 14	7 01	12 49	18 44	5	
	4	5 34	11 47	19 09	7 22	13 15	18 49	4	
	3	5 20	11 27	19 03	7 36	13 35	18 55	3	
	2	5 09	11 07	18 54	7 47	13 55	19 04	2	
	1	5 05	11 01	18 52	7 51	14 01	19 06	1	
	0	5 03	10 53	18 46	7 53	14 09	19 12	0	
After.	1	5 05	10 51	18 42	7 51	14 11	19 16	1	After.
	2	5 11	10 55	18 40	7 45	14 07	19 18	2	
	3	5 18	11 03	18 41	7 38	13 59	19 17	3	
	4	5 32	11 15	18 39	7 24	13 47	19 19	4	
	5	5 50	11 35	18 41	7 06	13 27	19 17	5	
	6	6 11	11 55	18 40	6 45	13 07	19 18	6	
	7	6 35	12 19	18 40	6 21	12 43	19 18	7	

TABLE VIII.—PORT TOWNSHEND.

Days from moon's greatest declination.		SOUTH DECLINATION.			NORTH DECLINATION.			Days from moon's greatest declination.	
		Low water.	High water.	Low water.	Low water.	High water.	Low water.		
		h. m.	h. m.	h. m.	h. m.	h. m.	h. m.		
Before.	7	6 05	12 26	18 05	5 39	12 26	18 31	7	Before.
	6	6 38	13 14	18 20	5 06	11 38	18 16	6	
	5	7 18	14 14	18 40	4 26	10 38	17 56	5	
	4	8 13	15 52	19 23	3 31	9 00	17 13	4	
	3	8 36	16 52	20 00	3 08	8 00	16 36	3	
	2	8 43	17 30	20 31	3 01	7 22	16 05	2	
	1	8 12	17 04	20 36	3 32	7 48	16 00	1	
	0	7 40	16 28	20 32	4 04	8 24	16 04	0	
After.	1	7 18	15 52	20 18	4 26	9 00	16 18	1	After.
	2	6 59	15 14	19 59	4 45	9 38	16 37	2	
	3	6 38	14 32	19 38	5 06	10 20	16 58	3	
	4	6 24	14 02	19 22	5 20	10 50	17 14	4	
	5	6 10	13 26	19 00	5 34	11 26	17 36	5	
	6	5 59	12 50	18 35	5 45	12 02	18 01	6	
	7	5 42	12 26	18 28	6 02	12 26	18 08	7	

The days from the greatest declination are written in the first and last columns of the table. The second, third, and fourth columns refer to south declination, and fifth, sixth, and seventh to north, and the reverse for Key West. The second column gives the number which is to be added, according to the declination, to the time of high water, obtained by means of Tables IV and V, to give the next low water, which is the small low water, *b*, of diagram I. The third contains the numbers to be added to the same to give the second or large high water, *c*, of diagram I. The fourth, the numbers to be added to the same to give the second or large low water, *d*, of diagram I. The succeeding columns give the numbers to be used in the same way for north declination to obtain the low water, *b*, (large,) of diagram II; the high water, *c*, (small,) and the low water, *d*, (small,) of the same diagram. The rise and fall of the same successive tides may be obtained by inspection from Table IX, in which the first column at the side contains the time of transit, and the successive columns the numbers corresponding to that time, and to the number of days from greatest declination. The arrangement of this table is like that already given.

The numbers for the small ebb tide, *a b* of diagram I, or *c d* of diagram II, are first given; then those for small low and large high waters, *b c* for diagram I, and *d e* of diagram II; next, the large ebb tide, *c d* of diagram I, or *a b* of diagram II; and lastly, from the large low water to the small high water, *d e* of diagram I, or *b c* of diagram II.

TABLE IX.—KEY WEST.

Time of moon's transit.	SMALL EBB TIDE.															SMALL LOW TO LARGE HIGH WATER.															Time of moon's transit.
	Days from moon's greatest declination.															Days from moon's greatest declination.															
	Before—								After—							Before—								After—							
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	
H.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	H.
0	1.6	1.4	1.1	1.0	0.8	0.7	0.7	0.7	0.7	0.8	0.9	1.1	1.2	1.5	1.8	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.6	1.7	1.7	1.6	1.5	1.4	0
1	1.6	1.4	1.1	1.0	0.8	0.7	0.7	0.7	0.7	0.8	0.9	1.1	1.2	1.5	1.8	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.6	1.7	1.7	1.6	1.5	1.4	1
2	1.6	1.4	1.1	1.0	0.8	0.7	0.7	0.7	0.7	0.8	0.9	1.1	1.2	1.5	1.8	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.6	1.7	1.7	1.6	1.5	1.4	2
3	1.5	1.3	1.0	0.9	0.7	0.6	0.6	0.6	0.6	0.7	0.8	1.0	1.1	1.4	1.7	1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.6	1.6	1.5	1.4	1.3	3
4	1.3	1.1	0.8	0.7	0.5	0.4	0.4	0.4	0.4	0.5	0.6	0.8	0.9	1.2	1.5	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.3	1.4	1.4	1.3	1.2	1.1	4
5	1.1	0.9	0.6	0.5	0.3	0.2	0.2	0.2	0.2	0.3	0.4	0.6	0.7	1.0	1.3	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.1	1.2	1.2	1.1	1.0	0.9	5
6	1.0	0.8	0.5	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.5	0.6	0.9	1.2	0.8	0.8	0.9	1.0	1.0	1.1	1.1	1.1	1.1	1.0	1.1	1.1	1.0	0.9	0.8	6
7	1.0	0.8	0.5	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.5	0.6	0.9	1.2	0.8	0.8	0.9	1.0	1.0	1.1	1.1	1.1	1.1	1.0	1.1	1.1	1.0	0.9	0.8	7
8	1.1	0.9	0.6	0.5	0.3	0.2	0.2	0.2	0.2	0.3	0.4	0.6	0.7	1.0	1.3	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.1	1.2	1.2	1.1	1.0	0.9	8
9	1.3	1.1	0.8	0.7	0.5	0.4	0.4	0.4	0.4	0.5	0.6	0.8	0.9	1.2	1.5	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.3	1.4	1.4	1.3	1.2	1.1	9
10	1.5	1.3	1.0	0.9	0.7	0.6	0.6	0.6	0.6	0.7	0.8	1.0	1.1	1.4	1.7	1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.6	1.6	1.5	1.4	1.3	10
11	1.6	1.4	1.1	1.0	0.8	0.7	0.7	0.7	0.7	0.8	0.9	1.1	1.2	1.5	1.8	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.6	1.7	1.7	1.6	1.5	1.4	11

TABLE IX.—KEY WEST—Continued.

Time of moon's transit.	LARGE EBB TIDE.															LARGE LOW TO SMALL HIGH WATER.															Time of moon's transit.
	Days from moon's greatest declination.															Days from moon's greatest declination.															
	Before—								After—							Before—								After—							
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	
H.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	H.
0	1.4	1.6	1.9	2.0	2.2	2.3	2.3	2.3	2.3	2.2	2.1	1.9	1.8	1.5	1.2	1.6	1.5	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.4	1.3	1.3	1.4	1.5	1.6	0
1	1.4	1.6	1.9	2.0	2.2	2.3	2.3	2.3	2.3	2.2	2.1	1.9	1.8	1.5	1.2	1.6	1.5	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.4	1.3	1.3	1.4	1.5	1.6	1
2	1.4	1.6	1.9	2.0	2.2	2.3	2.3	2.3	2.3	2.2	2.1	1.9	1.8	1.5	1.2	1.6	1.5	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.4	1.3	1.3	1.4	1.5	1.6	2
3	1.3	1.5	1.8	1.9	2.1	2.2	2.2	2.2	2.2	2.1	2.0	1.8	1.7	1.4	1.1	1.5	1.4	1.4	1.3	1.3	1.2	1.2	1.2	1.2	1.3	1.2	1.2	1.3	1.4	1.5	3
4	1.1	1.3	1.6	1.7	1.9	2.0	2.0	2.0	2.0	1.9	1.8	1.6	1.5	1.2	0.9	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.1	1.2	1.3	4
5	0.9	1.1	1.4	1.5	1.7	1.8	1.8	1.8	1.8	1.7	1.6	1.4	1.3	1.0	0.7	1.1	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.9	1.0	1.1	5
6	0.8	1.0	1.3	1.4	1.6	1.7	1.7	1.7	1.7	1.6	1.5	1.3	1.2	0.9	0.6	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.8	0.9	1.0	6
7	0.8	1.0	1.3	1.4	1.6	1.7	1.7	1.7	1.7	1.6	1.5	1.3	1.2	0.9	0.6	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.8	0.9	1.0	7
8	0.9	1.1	1.4	1.5	1.7	1.8	1.8	1.8	1.8	1.7	1.6	1.4	1.3	1.0	0.7	1.1	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.9	1.0	1.1	8
9	1.1	1.3	1.6	1.7	1.9	2.0	2.0	2.0	2.0	1.9	1.8	1.6	1.5	1.2	0.9	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.1	1.2	1.3	9
10	1.3	1.5	1.8	1.9	2.1	2.2	2.2	2.2	2.2	2.1	2.0	1.8	1.7	1.4	1.1	1.5	1.4	1.4	1.3	1.3	1.2	1.2	1.2	1.2	1.3	1.2	1.2	1.3	1.4	1.5	10
11	1.4	1.6	1.9	2.0	2.2	2.3	2.3	2.3	2.3	2.2	2.1	1.9	1.8	1.5	1.2	1.6	1.5	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.4	1.3	1.3	1.4	1.5	1.6	11

TABLE IX.—SAN DIEGO.

Time of moon's transit.	SMALL EBB TIDE, OR FROM SMALL HIGH WATER TO SMALL LOW WATER.															FROM SMALL LOW WATER TO LARGE HIGH WATER.															Time of moon's transit.
	Days from moon's greatest declination.															Days from moon's greatest declination.															
	Before—								After—							Before—								After—							
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	
H.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	H.
0	4.0	3.4	3.0	2.6	2.3	2 1	2.0	2.0	2.1	2.3	2.7	3.2	3.8	4.6	5.2	5.1	4.9	4.7	4.5	4.4	4.3	4.2	4.2	4.1	4.1	4.0	4.0	3.9	3.9	4.0	0
1	3.8	3.2	2.8	2.4	2 1	1.9	1.8	1.8	1.9	2.1	2.5	3.0	3.6	4.4	5.0	4.9	4.7	4.5	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.8	1
2	3.5	2.9	2.5	2.1	1.8	1.6	1.5	1.5	1.6	1.8	2.2	2.7	3.3	4.1	4.7	4.6	4.4	4.2	4.0	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.4	3.4	3.5	2
3	3.0	2.4	2.0	1.6	1.3	1.1	1.0	1.0	1.1	1.3	1.7	2.2	2.8	3.6	4.2	4.1	3.8	3.7	3.5	3.4	3.3	3.2	3.2	3.1	3.1	3.0	3.0	2.9	2.9	3.0	3
4	2.2	1.6	1.2	0.8	0.5	0.3	0.2	0.2	0.3	0.5	0.9	1.4	2.0	2.8	3.4	3.3	3.1	2.9	2.7	2.6	2.5	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1	2.2	4
5	1.7	1.1	0.7	0.3	0.0	–.2	–.3	–.3	–.2	0 0	0.4	0.9	1.[illegible]	2.3	2.9	2.8	2.6	2 4	2.2	2.1	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.7	5
6	1.8	1.2	0.8	0.4	0.1	–.1	–.2	–.2	–.1	0.1	0.5	1.0	1.6	2.4	3.0	2.9	2.7	2.5	2.3	2.2	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.8	6
7	2.3	1.7	1.3	0.9	0.6	0.4	0.3	0.3	0.4	0.6	1.0	1.5	2.1	2.9	3.5	3.4	3.2	3.0	2.8	2.7	2.6	2.5	2.5	2.4	2.4	2.3	2.3	2.2	2.2	2.3	7
8	2.9	2.3	1.9	1.5	1.2	1.0	0.9	0.9	1.0	1.2	1 6	2.1	2.7	3.5	4.1	4.0	3.8	3.6	3.4	3.3	3.2	3.1	3.1	3.0	3.0	2.9	2.9	2.8	2.8	2.9	8
9	3.7	3.1	2.7	2.3	2.0	1.8	1.7	1.7	1.8	2.0	2.4	2.9	3.5	4.3	4.9	4.8	4.6	4.4	4.2	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.7	9
10	4.2	3.6	3.2	2.8	2.5	2.3	2.2	2.2	2.3	2.5	2.9	3.4	4.0	4.8	5.4	5.3	5.1	4.9	4.7	4.6	4.5	4.4	4.4	4.3	4.3	4.2	4 2	4.1	4.1	4.2	10
11	4.3	3.7	3.3	2.9	2 6	2.4	2.3	2.3	2.4	2.6	3.0	3.5	4.1	4.9	5.5	5.4	5.2	5.0	4.8	4.7	4.6	4.5	4.5	4.4	4.4	4.3	4.3	4.2	4.2	4.3	11
	From *a* to *b*....................Diagram I. From *c* to *d*....................Diagram II.															From *b* to *c*....................Diagram I. From *d* to *e*....................Diagram II.															

TABLE IX.—SAN DIEGO—Continued.

Time of moon's transit.	LARGE EBB TIDE, OR FROM LARGE HIGH WATER TO LARGE LOW WATER.															FROM LARGE LOW WATER TO SMALL HIGH WATER.															Time of moon's transit.
	Days from moon's greatest declination.															Days from moon's greatest declination.															
	Before—								After—							Before—								After—							
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	
H.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	H.
0	5.2	5.8	6.2	6.6	6.9	7.1	7.2	7.2	7.1	6.9	6.5	6 0	5.4	4.6	4.0	4.1	4.3	4.5	4.7	4.8	4 9	5.0	5.0	5.1	5.1	5.2	5.2	5.3	5.3	5.2	0
1	5.0	5.6	6.0	6.4	6.7	6.9	7 0	7.0	6.9	6.7	6.3	5.8	5.2	4.4	3.8	3.9	4.1	4.3	4.5	4.6	4.7	4.8	4.8	4.9	4.9	5.0	5.0	5.1	5.1	5.0	1
2	4.7	5.3	5.7	6.1	6.4	6.6	6.7	6.7	6.6	6.4	6.0	5.5	4.9	4.1	3.5	3 6	3.8	4.0	4.2	4.3	4.4	4.5	4.5	4.6	4.6	4.7	4.7	4.8	4.8	4.7	2
3	4.2	4.8	5 2	5.6	5.9	6.1	6.2	6.2	6.1	5.9	5.5	5.0	4.4	3.6	3.0	3.1	3.3	3.5	3.7	3.8	3.9	4.0	4.0	4.1	4.1	4.2	4.2	4.3	4.3	4.2	3
4	3.4	4.0	4.4	4.8	5 1	5 3	5.4	5.4	5.3	5.1	4.7	4.2	3.6	2.8	2.2	2.3	2.5	2.7	2.9	3.0	3.1	3 2	3.2	3.3	3.3	3.4	3.4	3.5	3.5	3.4	4
5	2.9	3.5	3.9	4.3	4.6	4.8	4.9	4.9	4.8	4.6	4.2	3.7	3 1	2.3	1.7	1.8	2.0	2.3	2.4	2.5	2.6	2.7	2.7	2.8	2.8	2.9	2.9	3.0	3.0	2.9	5
6	3.0	3.6	4.0	4.4	4.7	4.9	5.0	5.0	4.9	4.7	4.3	3.8	3.2	2.4	1.8	1.9	2.1	2.3	2 5	2.6	2.7	2.8	2.8	2.9	2.9	3.0	3.0	3.1	3.1	3.0	6
7	3.5	4.1	4.5	4.9	5.2	5.4	5.5	5.5	5.4	5.2	4.8	4.3	3.7	2.9	2.3	2.4	2.6	2.8	3.0	3.1	3.2	3.3	3.3	3.4	3.4	3.5	3.5	3.6	3.6	3.5	7
8	4.1	4.7	5.1	5.5	5.8	6.0	6.1	6.1	6.0	5.8	5.4	4.9	4.3	3.5	2.9	3.0	3.2	3.4	3.6	3.7	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.2	4.2	4.1	8
9	4.9	5.5	5.9	6.3	6.6	6.8	6.9	6 9	6.8	6.6	6.2	5.7	5.1	4.3	3.7	3.8	4.0	4.2	4.4	4.5	4.6	4.7	4.7	4.8	4.8	4.9	4.9	5.0	5.0	4.9	9
10	5.4	6.0	6.4	6.8	7.1	7.3	7.4	7.4	7.3	7.1	6.7	6.2	5.6	4.8	4.2	4.3	4.5	4.7	4.9	5.0	5.1	5.2	5.2	5.3	5.3	5.4	5.4	5.5	5.5	5.4	10
11	5.5	6.1	6.5	6 9	7.2	7.4	7.5	7.5	7.4	7.2	6.8	6.3	5.7	4.9	4.3	4.4	4.6	4.8	5.0	5.1	5.2	5.3	5.3	5.4	5.4	5.5	5.5	5.6	5.6	5.5	11
	From *c* to *d*....................Diagram I. From *a* to *b*....................Diagram II.															From *d* to *e*....................Diagram I. From *b* to *c*....................Diagram II.															

TABLE IX.—SAN FRANCISCO.

SMALL EBB TIDE, OR FROM SMALL HIGH WATER TO SMALL LOW WATER.

Days from moon's greatest declination.

Hours of moon's transit.	Before— 7	6	5	4	3	2	1	0	After— 1	2	3	4	5	6	7
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0	4.7	4.0	3.4	2.9	2.4	2.0	1.8	1.7	1.7	1.9	2.2	2.6	3.1	3.7	4.4
1	4.5	3.8	3.2	2.7	2.2	1.8	1.6	1.5	1.5	1.7	2.0	2.4	2.9	3.5	4.2
2	4.3	3.6	3.0	2.5	2.0	1.6	1.4	1.3	1.3	1.5	1.8	2.2	2.7	3.3	4.0
3	4.0	3.3	2.7	2.2	1.7	1.3	1.1	1.0	1.0	1.2	1.5	1.9	2.4	3.0	3.7
4	3.6	2.9	2.3	1.8	1.3	0.9	0.7	0.6	0.6	0.8	1.1	1.5	2.0	2.6	3.3
5	3.2	2.5	1.9	1.4	0.9	0.5	0.3	0.2	0.2	0.4	0.7	1.1	1.6	2.2	2.9
6	3.2	2.5	1.9	1.4	0.9	0.5	0.3	0.2	0.2	0.4	0.7	1.1	1.6	2.2	2.9
7	3.4	2.7	2.1	1.6	1.1	0.7	0.5	0.4	0.4	0.6	0.9	1.3	1.8	2.4	3.1
8	3.8	3.1	2.5	2.0	1.5	1.1	0.9	0.8	0.8	1.0	1.3	1.7	2.2	2.8	3.5
9	4.1	3.4	2.8	2.3	1.8	1.4	1.2	1.1	1.1	1.3	1.6	2.0	2.5	3.1	3.8
10	4.5	3.8	3.2	2.7	2.2	1.8	1.6	1.5	1.5	1.7	2.0	2.4	2.9	3.5	4.2
11	4.7	4.0	3.4	2.9	2.4	2.0	1.8	1.7	1.7	1.9	2.2	2.6	3.1	3.7	4.4

From *a* to *b*....................................Diagram I.
From *c* to *d*....................................Diagram II.

FROM SMALL LOW WATER TO LARGE HIGH WATER.

Days from moon's greatest declination.

Hours of moon's transit.	Before— 7	6	5	4	3	2	1	0	After— 1	2	3	4	5	6	7
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0	5.2	4.9	4.6	4.5	4.0	3.7	3.4	3.2	3.1	3.0	3.1	3.1	3.3	3.4	3.5
1	5.0	4.7	4.4	4.3	3.8	3.5	3.2	3.0	2.9	2.8	2.9	2.9	3.1	3.2	3.3
2	4.8	4.5	4.2	4.1	3.6	3.3	3.0	2.8	2.7	2.6	2.7	2.7	2.9	3.0	3.1
3	4.5	4.2	3.9	3.8	3.3	3.0	2.7	2.5	2.4	2.3	2.4	2.4	2.6	2.7	2.8
4	4.1	3.8	3.5	3.4	2.9	2.6	2.3	2.1	2.0	1.9	2.0	2.0	2.2	2.3	2.4
5	3.7	3.4	3.1	3.0	2.5	2.2	1.9	1.7	1.6	1.5	1.6	1.6	1.8	1.9	2.0
6	3.7	3.4	3.1	3.0	2.5	2.2	1.9	1.7	1.6	1.5	1.6	1.6	1.8	1.9	2.0
7	3.9	3.6	3.3	3.2	2.7	2.4	2.1	1.9	1.8	1.7	1.8	1.8	2.0	2.1	2.2
8	4.3	4.0	3.7	3.6	3.1	2.8	2.5	2.3	2.2	2.1	2.2	2.2	2.4	2.5	2.6
9	4.6	4.3	4.0	3.9	3.4	3.1	2.8	2.6	2.5	2.4	2.5	2.5	2.7	2.8	2.9
10	5.0	4.7	4.4	4.3	3.8	3.5	3.2	3.0	2.9	2.8	2.9	2.9	3.1	3.2	3.3
11	5.2	4.9	4.6	4.5	4.0	3.7	3.4	3.2	3.1	3.0	3.1	3.1	3.3	3.4	3.5

From *b* to *e*....................................Diagram I.
From *d* to *e*....................................Diagram II.

TABLE IX.—SAN FRANCISCO—Continued.

LARGE EBB TIDE, OR FROM LARGE HIGH WATER TO LARGE LOW WATER.

Days from moon's greatest declination.

Time of moon's transit.	Before— 7	6	5	4	3	2	1	0	After— 1	2	3	4	5	6	7
H.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0	3.9	4.6	5.2	5.7	6.2	6.6	6.8	6.9	6.9	6.7	6.4	6.0	5.5	4.9	4.2
1	3.7	4.4	5.0	5.5	6.0	6.4	6.6	6.7	6.7	6.5	6.2	5.8	5.3	4.7	4.0
2	3.5	4.2	4.8	5.3	5.8	6.2	6.4	6.5	6.5	6.3	6.0	5.6	5.1	4.5	3.8
3	3.2	3.9	4.5	5.0	5.5	5.9	6.1	6.2	6.2	6.0	5.7	5.3	4.8	4.2	3.5
4	2.8	3.5	4.1	4.6	5.1	5.5	5.7	5.8	5.8	5.6	5.3	4.9	4.4	3.8	3.1
5	2.4	3.1	3.7	4.2	4.7	5.1	5.3	5.4	5.4	5.2	4.9	4.5	4.0	3.4	2.7
6	2.4	3.1	3.7	4.2	4.7	5.1	5.3	5.4	5.4	5.2	4.9	4.5	4.0	3.4	2.7
7	2.6	3.3	3.9	4.4	4.9	5.3	5.5	5.6	5.6	5.4	5.1	4.7	4.2	3.6	2.9
8	3.0	3.7	4.3	4.8	5.3	5.7	5.9	6.0	6.0	5.8	5.5	5.1	4.6	4.0	3.3
9	3.3	4.0	4.6	5.1	5.6	6.0	6.2	6.3	6.3	6.1	5.8	5.4	4.9	4.3	3.6
10	3.7	4.4	5.0	5.5	6.0	6.4	6.6	6.7	6.7	6.5	6.2	5.8	5.3	4.7	4.0
11	3.9	4.6	5.2	5.7	6.2	6.6	6.8	6.9	6.9	6.7	6.4	6.0	5.5	4.9	4.2

From *c* to *d* ....Diagram I.
From *a* to *b*....................................Diagram II.

FROM LARGE LOW WATER TO SMALL HIGH WATER.

Days from moon's greatest declination.

Time of moon's transit.	Before— 7	6	5	4	3	2	1	0	After— 1	2	3	4	5	6	7
H.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0	3.4	3.7	4.0	4.1	4.6	4.9	5.2	5.4	5.5	5.6	5.6	5.5	5.3	5.2	5.2
1	3.2	3.5	3.8	3.9	4.4	4.7	5.0	5.2	5.3	5.4	5.3	5.3	5.1	5.0	5.0
2	3.0	3.3	3.6	3.7	4.2	4.5	4.8	5.0	5.1	5.2	5.1	5.1	4.9	4.8	4.8
3	2.7	3.0	3.3	3.4	3.9	4.2	4.5	4.7	4.8	4.9	4.8	4.8	4.6	4.5	4.5
4	2.3	2.6	2.9	3.0	3.5	3.8	4.1	4.3	4.4	4.5	4.4	4.4	4.2	4.1	4.1
5	1.9	2.2	2.5	2.6	3.1	3.4	3.7	3.9	4.0	4.1	4.0	4.0	3.8	3.7	3.7
6	1.9	2.2	2.5	2.6	3.1	3.4	3.7	3.9	4.0	4.1	4.0	4.0	3.8	3.7	3.7
7	2.1	2.4	2.7	2.8	3.3	3.6	3.9	4.1	4.2	4.3	4.2	4.2	4.0	3.9	3.9
8	2.5	2.8	3.1	3.2	3.7	4.0	4.3	4.5	4.6	4.7	4.6	4.6	4.4	4.3	4.3
9	2.8	3.1	3.4	3.5	4.0	4.3	4.6	4.8	4.9	5.0	4.9	4.9	4.7	4.6	4.6
10	3.2	3.5	3.8	3.9	4.4	4.7	5.0	5.2	5.3	5.4	5.3	5.3	5.1	5.0	5.0
11	3.4	3.7	4.0	4.1	4.6	4.9	5.2	5.4	5.5	5.6	5.5	5.5	5.3	5.2	5.2

From *d* to *e*....................................Dingram I.
From *b* to *c*....................................Dingram II.

TABLE IX.—ASTORIA.

SMALL EBB TIDE, OR FROM SMALL HIGH WATER TO SMALL LOW WATER.

Hours of moon's transit.	Days from moon's greatest declination.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	6
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0	7.4	6.7	6.0	5.4	5.0	4.6	4.5	4.5	4.6	4.7	5.1	5.5	6.2	6.9	7.8
1	7.5	6.8	6.1	5.5	5.1	4.7	4.6	4.6	4.7	4.8	5.2	5.6	6.3	7.0	7.9
2	7.2	6.5	5.8	5.2	4.8	4.4	4.3	4.3	4.4	4.5	4.9	5.3	6.0	6.7	7.6
3	6.6	5.9	5.2	4.6	4.2	3.8	3.7	3.7	3.8	3.9	4.3	4.7	5.4	6.1	7.0
4	5.9	5.2	4.5	3.9	3.5	3.1	3.0	3.0	3.1	3.2	3.6	4.0	4.7	5.4	6.3
5	5.2	4.5	3.8	3.2	2.8	2.4	2.3	2.3	2.4	2.5	2.9	3.3	4.0	4.7	5.6
6	4.8	4.1	3.4	2.8	2.4	2.0	1.9	1.9	2.0	2.1	2.5	2.9	3.6	4.3	5.2
7	5.0	4.3	3.6	3.0	2.6	2.2	2.1	2.1	2.2	2.3	2.7	2.1	3.8	4.5	5.4
8	5.5	4.8	4.1	3.5	3.1	2.7	2.6	2.6	2.7	2.8	3.2	3.6	4.3	5.0	5.9
9	6.3	5.6	4.9	4.3	3.9	3.5	3.4	3.4	3.5	3.6	4.0	4.4	5.1	5.8	6.7
10	7.0	6.3	5.6	5.0	4.6	4.2	4.1	4.1	4.2	4.3	4.7	5.1	5.8	6.5	7.4
11	7.3	6.6	6.9	5.3	4.9	4.5	4.4	4.4	4.5	4.6	5.0	5.4	6.1	6.8	7.7

From *a* to *b*....................................Diagram I.
From *c* to *d*....................................Diagram II.

FROM SMALL LOW WATER TO LARGE HIGH WATER.

Days from moon's greatest declination.															Hours of moon's transit.
Before—								After—							
7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	
Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	
8.0	7.8	7.5	7.2	6.8	6.4	6.3	6.2	6.1	6.2	6.2	6.3	6.3	6.3	6.4	0
8.1	7.9	7.6	7.3	6.9	6.5	6.4	6.3	6.2	6.3	6.3	6.4	6.4	6.4	6.5	1
7.8	7.6	7.3	7.0	6.6	6.2	6.1	6.0	5.9	6.0	6.0	6.1	6.1	6.1	6.2	2
7.2	7.0	6.7	6.4	6.0	5.6	5.5	5.4	5.3	5.4	5.4	5.5	5.5	5.5	5.6	3
6.5	6.3	6.0	5.7	5.3	4.9	4.8	4.7	4.6	4.7	4.7	4.8	4.8	4.8	4.9	4
5.8	5.6	5.3	5.0	4.6	4.2	4.1	4.0	3.9	4.0	4.0	4.1	4.1	4.1	4.2	5
5.4	5.2	4.9	4.6	4.2	3.8	3.7	3.6	3.5	3.6	3.6	3.7	3.7	3.7	3.8	6
5.6	5.4	5.1	4.8	4.4	4.0	3.9	3.8	3.7	3.8	3.8	3.9	3.9	3.9	4.0	7
6.1	5.9	5.6	5.3	4.9	4.5	4.4	4.3	4.2	4.3	4.3	4.4	4.4	4.4	4.5	8
6.9	6.7	6.4	6.1	5.7	5.3	5.2	5.1	5.0	5.1	5.1	5.2	5.2	5.2	5.3	9
7.6	7.4	7.1	6.8	6.4	6.0	5.9	5.8	5.7	5.8	5.8	5.9	5.9	5.9	6.0	10
7.9	7.7	7.4	7.1	6.7	6.3	6.2	6.1	6.0	6.1	6.1	6.2	6.2	6.2	6.3	11

From *b* to *c*.................. ....Diagram I.
From *d* to *e*....................................Diagram II.

TABLE IX.—ASTORIA—Continued.

LARGE EBB TIDE, OR FROM LARGE HIGH WATER TO LARGE LOW WATER.

Hours of moon's transit.	Days from moon's greatest declination.														
	Before—								After—						
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0	7.0	7.7	8.4	9.0	9.4	9.8	9.9	9.9	9.8	9.7	9.3	8.9	8.2	7.5	6.6
1	7.1	7.8	8.5	9.1	9.5	9.9	10.0	10.0	9.9	9.8	9.4	9.0	8.3	7.6	6.7
2	6.8	7.5	8.2	8.8	9.2	9.6	9.7	9.7	9.6	9.5	9.1	8.7	8.0	7.3	6.4
3	6.2	6.9	7.6	8.2	8.6	9.0	9.1	9.1	9.0	8.9	8.5	8.1	7.4	6.7	5.8
4	5.5	6.2	6.9	7.5	7.9	8.3	8.4	8.4	8.3	8.2	7.8	7.4	6.7	6.0	5.1
5	4.8	5.5	6.2	6.8	7.2	7.6	7.7	7.7	7.6	7.5	7.1	6.7	6.0	5.3	4.4
6	4.4	5.1	5.8	6.4	6.8	7.2	7.3	7.3	7.2	7.1	6.7	6.3	5.6	4.9	4.0
7	4.6	5.3	6.0	6.6	7.0	7.4	7.5	7.5	7.4	7.3	6.9	6.5	5.8	5.1	4.2
8	5.1	5.8	6.5	7.1	7.5	7.9	8.0	8.0	7.9	7.8	7.4	7.0	6.3	5.6	4.7
9	5.9	6.6	7.3	7.9	8.3	8.7	8.8	8.8	8.7	8.6	8.2	7.8	7.1	6.4	5.5
10	6.6	7.3	8.0	8.6	9.0	9.4	9.5	9.5	9.4	9.3	8.9	8.5	7.8	7.1	6.2
11	6.9	7.6	8.3	8.9	9.3	9.7	9.8	9.8	9.7	9.6	9.2	8.8	8.1	7.4	7.5

From *c* to *d*....................................Diagram I.
From *a* to *b*....................................Diagram II.

FROM LARGE LOW WATER TO SMALL HIGH WATER.

Days from moon's greatest declination.															Hours of moon's transit.
Before—								After—							
7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	
Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	
6.4	6.6	6.9	7.2	7.6	8.0	8.1	8.2	8.3	8.2	8.2	8.1	8.1	8.1	8.0	0
6.5	6.7	7.0	7.3	7.7	8.1	8.2	8.3	8.4	8.3	8.3	8.2	8.2	8.2	8.1	1
6.2	6.4	6.7	7.0	7.4	7.8	7.9	8.0	8.1	8.0	8.0	7.9	7.9	7.9	7.8	2
5.6	5.8	6.1	6.4	6.8	7.2	7.3	7.4	7.5	7.4	7.4	7.3	7.3	7.3	7.2	3
4.9	5.1	5.4	5.7	6.1	6.5	6.6	6.7	6.8	6.7	6.7	6.6	6.6	6.6	6.5	4
4.2	4.4	4.7	5.0	5.4	5.8	5.9	6.0	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5
3.8	4.0	4.3	4.6	5.0	5.4	5.5	5.6	5.7	5.6	5.6	5.5	5.5	5.5	5.4	6
4.0	4.2	4.5	4.8	5.2	5.6	5.7	5.8	5.9	5.8	5.8	5.7	5.7	5.7	5.6	7
4.5	4.7	5.0	5.3	5.7	6.1	6.2	6.3	6.4	6.3	6.3	6.2	6.2	6.2	6.1	8
5.3	5.5	5.8	6.1	6.5	6.9	7.0	7.1	7.2	7.1	7.1	7.0	7.0	7.0	6.9	9
6.0	6.2	6.5	6.8	7.2	7.6	7.7	7.8	7.9	7.8	7.8	7.7	7.7	7.7	7.6	10
6.3	6.5	6.8	7.1	7.5	7.9	8.0	8.1	8.2	8.1	8.1	8.0	8.0	8.0	7.9	11

From *d* to *e*....................................Diagram I.
From *b* to *c*.............................. ......Diagram II.

TABLE IX.—PORT TOWNSHEND.

Hours of moon's transit.	SMALL EBB TIDE, OR FROM SMALL HIGH WATER TO SMALL LOW WATER.															FROM SMALL LOW WATER TO LARGE HIGH WATER.															Hours of moon's transit.
	Days from moon's greatest declination.															Days from moon's greatest declination.															
	Before—								After—							Before—								After—							
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	
	Feet.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	
0	4.5	5.6	6.9	8.0	8.6	8.9	8.8	8.8	8.7	8.7	8.5	8.0	7.3	6.6	5.5	3.5	3.9	4.6	6.0	7.2	8.4	9.0	9.5	9.6	9.4	9.2	8.7	8.2	7.9	7.1	0
1	4.5	5.6	6.9	8.0	8.6	8.9	8.8	8.8	8.7	8.7	8.5	8.0	7.3	6.6	5.5	3.5	3.9	4.6	6.0	7.2	8.4	9.0	9.5	9.6	9.4	9.2	8.7	8.2	7.9	7.1	1
2	4.4	5.5	6.8	7.9	8.5	8.8	8.7	8.7	8.6	8.6	8.4	7.9	7.2	6.5	5.4	3.4	3.8	4.5	5.9	7.1	8.3	8.9	9.4	9.5	9.3	9.1	8.6	8.1	7.8	7.0	2
3	4.1	5.2	6.5	7.6	8.2	8.5	8.4	8.4	8.3	8.3	8.1	7.6	6.9	6.2	5.1	3.1	3.5	4.2	5.6	6.8	8.0	8.6	9.1	9.2	9.0	8.8	8.3	7.8	7.5	6.7	3
4	3.5	4.6	5.9	7.6	7.6	7.9	7.8	7.8	7.7	7.7	7.5	7.0	6.3	5.6	4.5	2.5	2.9	3.6	5.0	6.2	7.4	8.0	8.5	8.6	8.4	8.2	7.7	7.2	6.9	6.1	4
5	3.1	4.2	5.5	6.6	7.2	7.5	7.4	7.4	7.3	7.3	7.1	6.6	5.9	5.2	4.1	2.1	2.5	3.2	4.6	5.8	7.0	7.6	8.1	8.2	8.0	7.8	7.3	6.8	6.5	5.7	5
6	3.1	4.2	5.5	6.6	7.2	7.5	7.4	7.4	7.3	7.3	7.1	6.6	5.9	5.2	4.1	2.1	2.5	3.2	4.6	5.8	7.0	7.6	8.1	8.2	8.0	7.8	7.3	6.8	6.5	5.7	6
7	3.3	4.4	5.7	6.8	7.4	7.7	7.6	7.6	7.5	7.5	7.3	6.8	6.1	5.4	4.3	2.3	2.7	3.4	4.8	6.0	7.2	7.8	8.3	8.4	8.2	8.0	7.5	7.0	6.7	5.9	7
8	3.5	4.6	5.9	7.0	7.6	7.9	7.8	7.8	7.7	7.7	7.5	7.0	6.3	5.6	4.5	2.5	2.9	3.6	5.0	6.2	7.4	8.0	8.5	8.6	8.4	8.2	7.7	7.2	6.9	6.1	8
9	3.7	4.8	6.1	7.2	7.8	8.1	8.0	8.0	7.9	7.9	7.7	7.2	6.5	5.8	4.7	2.7	3.1	3.8	5.2	6.4	7.6	8.2	8.7	8.8	8.6	8.4	7.9	7.4	7.1	6.3	9
10	4.1	5.2	6.5	7.6	8.2	8.5	8.4	8.4	8.3	8.3	8.1	7.6	6.9	6.2	5.1	3.1	3.5	4.2	5.6	6.8	8.0	8.6	9.1	9.2	9.0	8.8	8.3	7.8	7.5	6.7	10
11	4.4	5.5	6.8	7.9	8.5	8.8	8.7	8.7	8.6	8.6	8.4	7.9	7.2	6.5	5.4	3.4	3.8	4.5	5.9	7.1	8.3	8.9	9.4	9.5	9.3	9.1	8.6	8.1	7.8	7.0	11

TABLE IX.—PORT TOWNSHEND—Continued.

Hours of moon's transit.	LARGE EBB TIDE, OR FROM LARGE HIGH WATER TO LARGE LOW WATER.															FROM SMALL LOW WATER TO LARGE HIGH WATER.															Hours of moon's transit.
	Days from moon's greatest declination.															Days from moon's greatest declination.															
	Before—								After—							Before—								After—							
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	
	Feet.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	
0	6.5	5.4	4.1	3.0	2.4	2.1	2.2	2.2	2.3	2.3	2.5	3.0	3.7	4.4	5.5	7.5	7.1	6.4	5.0	3.8	2.6	2.0	1.5	1.4	1.6	1.8	2.3	2.8	3.1	3.9	0
1	6.5	5.4	4.1	3.0	2.4	2.1	2.2	2.2	2.3	2.3	2.5	3.0	3.7	4.4	5.5	7.5	7.1	6.4	5.0	3.8	2.6	2.0	1.5	1.4	1.6	1.8	2.3	2.8	3.1	3.9	1
2	6.4	5.3	4.0	2.9	2.3	2.0	2.1	2.1	2.2	2.2	2.4	2.9	3.6	4.3	5.4	7.4	7.0	6.3	4.9	3.7	2.5	1.9	1.4	1.3	1.5	1.7	2.2	2.7	3.0	3.8	2
3	6.1	5.0	3.7	2.6	2.0	1.7	1.8	1.8	1.9	1.9	2.1	2.6	3.3	4.0	5.1	7.1	6.7	6.0	4.6	3.4	2.2	1.6	1.1	1.0	1.2	1.4	1.9	2.4	2.7	3.5	3
4	5.5	4.4	3.1	2.0	1.4	1.1	1.2	1.2	1.3	1.3	1.5	2.0	2.7	3.4	4.5	6.5	6.1	5.4	4.0	2.8	1.6	1.0	0.5	0.4	0.6	0.8	1.3	1.8	2.1	2.9	4
5	5.1	4.0	2.7	1.6	1.0	0.7	0.8	0.8	0.9	0.9	1.1	1.6	2.3	3.0	4.1	6.1	5.7	5.0	3.6	2.4	1.2	0.6	0.1	0.0	0.2	0.4	0.9	1.4	1.7	2.5	5
6	5.1	4.0	2.7	1.6	1.0	0.7	0.8	0.8	0.9	0.9	1.1	1.6	2.3	3.0	4.1	6.1	5.7	5.0	3.6	2.4	1.2	0.6	0.1	0.0	0.2	0.4	0.9	1.4	1.7	2.5	6
7	5.3	4.2	2.9	1.8	1.2	0.9	1.0	1.0	1.1	1.1	1.3	1.8	2.5	3.2	4.3	6.3	5.9	5.2	3.8	2.6	1.4	0.8	0.3	0.2	0.4	0.6	1.1	1.6	1.9	2.7	7
8	5.5	4.4	3.1	2.0	1.4	1.1	1.2	1.2	1.3	1.3	1.5	2.0	2.7	3.4	4.5	6.5	6.1	5.4	4.0	2.8	1.6	1.0	0.5	0.4	0.6	0.8	1.3	1.8	2.1	2.9	8
9	5.7	4.6	3.3	2.2	1.6	1.3	1.4	1.4	1.5	1.5	1.7	2.2	2.9	3.6	4.7	6.7	6.3	5.6	4.2	3.0	1.8	1.2	0.7	0.6	0.8	1.0	1.5	2.0	2.3	3.1	9
10	6.1	5.0	3.7	2.6	2.0	1.7	1.8	1.8	1.9	1.9	2.1	2.6	3.3	4.0	5.1	7.1	6.7	6.0	4.6	3.4	2.2	1.6	1.1	1.0	1.2	1.4	1.9	2.4	2.7	3.5	10
11	6.4	5.3	4.0	2.9	2.3	2.0	2.1	2.1	2.2	2.2	2.4	2.9	3.6	4.3	5.4	7.4	7.0	6.3	4.9	3.7	2.5	1.9	1.4	1.3	1.5	1.7	2.2	2.7	3.0	3.8	11

Example VII.—Thus, in Example VI, the high water of February 7th was found to be 3.3 feet above mean low water. The declination being south, Diagram I applies, and this high water is the small one. To obtain the fall of the next low water or small low water, we enter Table IX, for San Francisco, with 0*h.* of moon's transit, and two days after the greatest declination in the first part of the table, and find 1.9 foot, which will be the difference in the height of this high and low water. Entering with the same transit and day in the second part, we find 3.0 feet, which is the rise of the large high above the small low water; the difference between 1.9 and 3.0 or 1.1 foot is the difference of height of the two successive high waters.

It is easy to see how, in this way, the soundings of a chart can be reduced to what they would be approximately at all the successive high and low waters.

TIDES OF THE GULF OF MEXICO.

On the coast of Florida, from Cape Florida around the peninsula to St. Mark's, the tides are of the ordinary kind, but with a daily inequality which, small at Cape Florida, goes on increasing as we proceed westward to Tortugas. From the Tortugas to St. Mark's the daily inequality is large and sensibly the same, giving the tides a great resemblance to those of the

Pacific coast, though the rise and fall is much smaller. Between St. Mark's and St. George's island, Apalachicola entrance, the tides change to the single day class, ebbing and flowing but once in the twenty-four (lunar) hours.

At St. George's island there are two tides a day, for three or four days, about the time of the moon's declination being zero. At other times there is but one tide a day, with a long stand at high water of from six to nine hours. From Cape St. Blas to and including the mouth of the Mississippi, the single day tides are very regular, and the small and irregular double tides appear only for two or three days, (and frequently even not at all,) about the time of zero declination of the moon. The stand at high and low water is comparatively short, seldom exceeding an hour.

To the west of the mouth of the Mississippi the double tides reappear. At Isle Dernière they are distinct, though a little irregular for three or four days near the time of the moon's zero declination. At all other times the single day type prevails, the double tides modifying it, however, in the shape of a long stand of from six to ten hours at high water. This stand is shortest at the time of the moon's greatest declination, sometimes being reduced to but one hour. At Calcasieu the tides are distinctly double, but with a large daily inequality. The rise and fall being small, they would often present to the ordinary observer the same appearance as at Isle Dernière. At Galveston the double tides are plainly perceptible, though small, for five or six days at the time of moon's zero declination. At other times they present the single day type, with the peculiarity that, after standing at high water for a short time, the water falls a small distance, and stands again at that height for several hours, then continues to fall to low water. Sometimes it falls very slowly for nine or ten hours following high water, and then acquires a more rapid rate to low water. At Aransas Pass and Brazos Santiago the single day tides prevail. Small, irregular, double tides are only perceived for two or three days at the moon's zero declination. At all other times there is but one high water in the day, with a long stand of from six to nine hours, during which there are often small, irregular fluctuations or a very slow fall. In the following table the mean rise and fall of tides at the above stations are given.

The highest high and the lowest low waters occur when the greatest declination of the moon happens at full or change; the least tide when the moon's declination is nothing at the first or last quarter. The rise and fall being so small, the times and heights are both much influenced by the winds, and are thus rendered quite irregular.

TABLE X.

Rise and fall at several stations on the Gulf of Mexico.

Stations.	Mean rise and fall of tides.		
	Mean.	At moon's greatest declination.	At moon's least declination.
	Feet.	*Feet.*	*Feet.*
St. George's island, Florida	1.1	1.8	0.6
Pensacola, Florida	1.0	1.5	0.4
Fort Morgan, Mobile bay, Alabama	1.0	1.5	0.4
Cat island, Mississippi	1.3	1.9	0.6
Southwest Pass, Louisiana	1.1	1.4	0.5
Isle Dernière, Louisiana	1.4	2.2	0.7
Entrance to Lake Calcasieu, Louisiana	1.9	2.4	1.7
Galveston, Texas	1.1	1.6	0.8
Aransas Pass, Texas	1.1	1.8	0.6
Brazos Santiago, Texas	0.9	1.2	0.5

TO DETERMINE THE RISE AND FALL OF THE TIDES FOR ANY GIVEN TIME FROM HIGH OR LOW WATER.

It is sometimes desirable to know how far the tide will rise in a given time from low water, or fall in a given time from high water, or to approximate to the time which has elapsed from low or high water, by knowing the rise and fall of the tide in the interval. If the proportion of the rise and fall in a given time were the same in the different ports, this would easily be shown in a single table, giving the proportional rise and fall, which, by referring to Table I, showing the rise and fall of the tide at the port, would give the rise and fall in feet and decimals. The proportion, however, is not the same in different ports, nor in the same ports for tides of different heights. The following Table XI shows the relation between the heights above low water for each half hour for New York and Old Point Comfort, and for spring and neap tides at each place. Units express the total rise of high water above low water, and the figures opposite to each half hour devote the proportional fall of the tide from high water onward to low water. For example, at New York, three hours after high water, a spring tide has fallen six-tenths (sixty hundredths) of the whole fall. Suppose the whole rise and fall of that day to be 5.4 feet, (Table I;) then, three hours after high water, the tide will have fallen 3.24 feet, or three feet three inches, nearly. Conversely, if we have observed that a spring tide has fallen three feet three inches, we may know that high water has passed about three hours.

TABLE XI.

Giving the height of the tide above low water for every half hour before or after high water, the total range being taken as equal to 1.

Time before or after high water.	New York.		Old Point Comfort.	
	Spring tide.	Neap tide.	Spring tide.	Neap tide.
h. m.				
0 0	1.00	1.00	1.00	1.00
0 30	0.98	0.98	0.98	0.98
1 0	0.94	0.93	0.95	0.94
1 30	0.89	0.86	0.88	0.87
2 0	0.80	0.72	0.80	0.78
2 30	0.72	0.59	0.70	0.68
3 0	0.60	0.45	0.59	0.57
3 30	0.49	0.31	0.49	0.44
4 0	0.39	0.19	0.37	0.34
4 30	0.28	0.10	0.26	0.22
5 0	0.18	0.02	0.17	0.13
5 30	0.09	0.00	0.08	0.05
6 0	0.05	....	0.03	0.01
6 30	0.00	....	0.00	0.00

TIDES IN COASTING.

By observing the time of high water and low water along the coast we find the places at which they are the same. The map of co-tidal lines (Sketch No. 65, C. S. Rep., 1857) shows that it is high water nearly at the same hour all along the coast from Sandy Hook to Cape Cañaveral; of course not in bays and harbors and up the rivers, but on the outer coast.

It is high water exactly at the same hour all along the line marked XII, seen on the chart, near Sandy Hook, and north and south of Hatteras, and, with small interruptions at Cape Lookout and Cape Fear, all the way to near Cape Cañaveral. This same line extends eastward to near Block island, and south of Nantucket, and then passes away from our coast. At full and change of the moon, along this line, (approximately,) it is high water at twelve o'clock, Greenwich time, the local time of high water depending upon the longitude of the place; or, to speak more correctly, in the average of a lunar month it is high water so many hours after the time of the moon's passing the meridian of Greenwich. By these lines, called co-tidal lines, we can determine what tidal currents the navigators must expect to meet in coasting; and for this purpose we divide the ports of the coast into two sets, those south and those north of New York.

The sailing lines of coasters, bound to southern ports this side of the straits of Florida, are marked upon the map, and also of those bound through the sounds to eastern ports, and outside to Halifax and European ports.

VESSELS TO AND FROM PORTS SOUTH OF NEW YORK.

South of Sandy Hook, New Jersey, the line of XII hours is nowhere more than 18 miles from the coast; that of XI¾ nowhere more than 35 miles; that of XI½ nowhere more than 48; and XI nowhere more than 110. The distance of these lines of XII to XI hours, (corresponding within four minutes to VII and VI of New York time, for different parts of the coast, is shown from Table A, where the first column gives the name of the place, and the second, third, fourth, fifth, respectively, the distances of the co-tidal lines of XII, XI¾, XI½, and XI hours. The distances are measured from the ports on perpendiculars to the co-tidal lines. They may be taken as if measured on the parallel of latitude at all the points for the line of XII hours, and at all between Sandy Hook and Cape Hatteras for the lines of XI¾ and XI½ hours.

A.

Names of locations.	Distance from coast, measured on perpendicular to co-tidal lines.			
	At XII hours.	At XI¾ hours.	At XI½ hours.	At XI hours.
	Nautical miles.	*Nautical miles.*	*Nautical miles.*	*Nautical miles.*
Sandy Hook	12	32	53	100
Barnegat	2	29	39	78
Cape May	15	30	46	92
Cape Henlopen	18	33	47	92
Assateague	7	22	36	82
Cape Henry	12	28	43	100
Cape Hatteras	....	8	20	63
Ocracoke inlet	....	11	26	71
Cape Lookout	....	7	18	56
Beaufort entrance, North Carolina	6	15	24	63
Cape Fear	....	6	16	55
Cape Roman	....	10	21	67
Charleston light	3	15	27	70
Port Royal entrance	5	17	29	78
Tybee entrance	6	17	31	82
St. Mary's entrance	12	25	40	110
St. John's entrance	17	35	48	....
Cape Cañaveral	16	....	....	....
Cape Florida	....	....	....	....

The co-tidal lines are in such directions that at 10, 20, and 30 miles from the coast, between Sandy Hook and the St. John's, there is but a variation of seven minutes, and even to Cape Cañaveral only of eight minutes.

Keeping ten miles from the shore the coaster would pass from 12 hours at Sandy Hook to 11 hours 45 minutes at Hatteras, and increase again irregularly to 12 hours 7 minutes at the St. John's, as shown more explicitly in table B. These three tracks of 10, 20, and 30 miles are inside of the cold wall of the Gulf Stream, and generally in the cold current, except at Cape Cañaveral.

B.

Names of stations.	Co-tidal hour at 10, 20, and 30 nautical miles from the coast, perpendicular to the coast.		
	Ten miles off.	Twenty miles off.	Thirty miles off.
	h. m.	*h. m.*	*h. m.*
Sandy Hook	12 0	11 52	11 45
Barnegat	11 52	11 44	11 35
Cape May	12 5	11 53	11 45
Cape Henlopen	12 7	11 57	11 48
Assateague	12 0	11 48	11 37
Cape Henry	12 5	11 48	11 42
Cape Hatteras	11 45	11 30	11 22
Ocracoke inlet	11 47	11 36	11 25
Cape Lookout	11 45	11 30	11 20
Beaufort entrance, N. C	11 55	11 38	11 25
Cape Fear	11 38	11 25	11 18
Cape Roman	11 45	11 33	11 24
Charleston light	11 52	11 38	11 25
Port Royal entrance	11 57	11 45	11 32
Tybee entrance	11 55	11 43	11 30
St. Mary's entrance	12 8	11 57	11 47
St. John's entrance	12 7	11 57	11 50
Cape Cañaveral	12 8	....	....
Cape Florida	13 10	....	....

It follows, then, as a general thing, from these two tables that the coaster, in passing from Sandy Hook to the St. John's would have the tides the same, within some fifteen minutes, as if he remained at Sandy Hook; so that having, for example, at high water, he would, according to the elapsed time, have the ebb and flood alternating every six hours and a quarter, nearly, as if he had remained near Sandy Hook. As the flood tide sets in generally to the northward and on shore, and the ebb to the southward and off shore, he would know by the time that elapsed from his departure and the period of the tide at which he started what tidal currents he might expect to meet as he passed along the coast. This, of course, is not peculiar to Sandy Hook as a point of departure, but would be true for any of the entrances given in the table, taking care not to mistake the time of tides within for that at the entrance.

By referring to George W. Blunt, esq., I have obtained the tracks of sailing and steam vessels passing from New York to ports to the south of it, as shown by the lines on the chart accompanying this paper. (See Sketch No. 65, C. S. Rep., 1857.) Tracing these on the map of co-tidal lines, I have determined how the navigator would find the tides as he passes from

port to port. The results are shown in the annexed table, (C,) in which the port between which and Sandy Hook the mariner passes is at the head of the table, and, at the side, the place off which the co-tidal hours will be found, as stated in the table.

C.

Off—	Co-tidal hours on sailing lines measured on parallels of latitude of places named in the first column, between New York and—							
	Delaware bay.	Chesapeake bay.	Ocracoke inlet.	Cape Fear.	Charleston.	Savannah.	St. John's.	Cape Florida.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
Sandy Hook	12 5	12 5	12 5	12 5	12 5	12 5	12 5	12 5
Barnegat	11 57	11 57	11 57	11 57	11 57	11 57	11 57	11 57
Cape May	12 10	11 52	11 45	11 45	11 45	11 45	11 45	11 45
Cape Henlopen	....	11 51	11 43	11 43	11 43	11 43	11 43	11 43
Assateague	....	11 55	11 33	11 33	11 33	11 33	11 33	11 33
Cape Henry	....	12 13	11 24	11 24	11 24	11 24	11 24	11 24
Cape Hatteras	....	....	11 48	11 48	11 48	11 48	11 48	11 48
Ocracoke inlet	....	....	....	11 42	11 42	11 42	11 42	11 42
Cape Lookout	....	....	....	11 39	11 39	11 39	11 32	11 24
Beaufort entrance	....	....	....	11 39	11 39	11 39	11 32	11 24
Cape Fear	....	....	....	....	11 36	11 36	11 24	11 0
Cape Roman	....	....	....	....	11 46	11 46	11 19	....
Charleston light	....	....	....	....	....	11 52	11 18	....
Port Royal entrance	....	....	....	....	....	12 3	11 18	....
Tybee entrance	....	....	....	....	....	....	11 16	....
St. Mary's entrance	....	....	....	....	....	....	11 55	....
St. John's entrance	....	....	....	....	....	....	12 10	....
Cape Cañaveral	....	....	....	....	....	....	....	....
Cape Florida	....	....	....	....	....	....	....	....

Thus, from Sandy Hook to Delaware bay, starting with 12 hours 5 minutes, off Barnegat there would be, at the same instant, 11 hours 57 minutes, and off Cape May 12 hours 10 minutes, so that the navigator would have the same succession of tides whether he remained at Sandy Hook or passed onward to Delaware bay, or whether he came from Delaware bay to Sandy Hook. So from Sandy Hook to Charleston he will find, at the same instant, 12 hours 5 minutes at Sandy Hook, 11 hours 57 minutes off Barnegat, 11 hours 45 minutes off Cape May, and so onward upon the parallels of latitude for the several points. *For all practical purposes, then, of coasting, the succession of the tides, and, of course, of the tidal currents of flood and ebb wi'l be the same as if the navigator remained stationary.* Leaving at low water he will meet the flood for 6 hours 15 minutes, and then the ebb for another 6 hours 15 minutes, and so on. It is the simplest of all rules that has thus come out of this investigation. That remarkable change of the temperature between the waters of the in-shore cold current and the warm waters of the Gulf Stream occurring in so short a distance that Lieutenant Bache called it the "cold wall," takes place at distances off the coast of from 170 to 29 miles, (see Table D,) between Sandy Hook and Cape Cañaveral, measured, from the several points named in the table, at right angles to the direction of the course, or measured along the parallels of latitude of the points, at distances from 195 to 28 miles, between Assateague and Cape Cañaveral, (Table D.) The points where the parallels north of Assateague meet this division line have not been accurately determined.

The annexed table shows these distances measured at right angles and on the parallels.

D.

Distance from coast to "cold wall" of Gulf Stream, off—	Measured at right angles to coast.	Measured on parallel of latitude.
	Naut. miles.	*Naut. miles.*
Sandy Hook	170	------------
Barnegat	135	------------
Cape May	137	------------
Cape Henlopen	137	------------
Assateague	95	195
Cape Henry	92	107
Cape Hatteras	30	31
Ocracoke inlet	53	52
Cape Lookout	53	65
Beaufort entrance	62	------------
Cape Fear	54	97
Cape Roman	57	103
Charleston light	61	95
Port Royal entrance	79	97
Tybee entrance	79	95
St. Mary's	90	87
St. John's	85	82
Cape Cañeveral	29	28
Cape Florida	------------	------------

The coasting line of thirty miles keeps inside of the cold wall all the way to Cañaveral, and all the routes traced on the chart from Sandy Hook to southern ports are on the inside of it. The Gulf Stream lines, as drawn on the chart, show how the route to Bermuda and to the Bahamas cuts the alternate bands of warm and cold water of the Gulf Stream.

Vessels to and from ports east of New York.

The plate shows the sailing lines of vessels bound from New York to eastern ports and to Halifax, outside. The annexed table (E) gives the Greenwich time of high water off the several points named in the first column on the routes to and from the places named in the heading of the table. The distances are measured at right angles to the co-tidal curves.

E.

Off—	Co-tidal hours on sailing lines between New York and—						
	Newport.	New Bedford	Nantucket.	Boston.	Portsmouth.	Portland.	Halifax.
	h. m.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
Sandy Hook	----------	----------	----------	----------	----------	----------	12 5
Throg's Point	16 16	16 16	16 16	16 16	16 16	16 16	----------
Fisher's island	13 48	13 48	13 48	13 48	13 48	13 48	----------
Block island	12 16	12 16	12 16	12 16	12 16	12 16	11 30
Monomoy	----------	----------	----------	16 10	16 10	16 10	----------
Cape Cod	----------	----------	----------	14 35	14 35	14 35	12 15
Cape Ann	----------	----------	----------	----------	15 00	14 40	----------
Portland	----------	----------	----------	----------	----------	15 30	----------

In passing from New York to an eastern port the first great change in the tides and tidal currents is between the East river and Long Island sound; the difference between Governor's island and Negro point, on Ward's island, at the eastern entrance to Hell Gate, is two hours and forty-five minutes. Between this point and Throg's Point the change is small. The mariner is now in the full tide of the sound, and between Throg's Point and Fisher's island there is a difference of time of but two hours and twenty minutes, the greatest part of which is at the head of the sound and at its entrance, that is, near Throg's Point and Fisher's island. From off New London to off Sand's Point the difference is but one hour and forty minutes, so that if the mariner, instead of remaining at Throg's Point, passes onward to Fisher's island he would lose but half a tide in the whole passage. In other words, he would have the same succession of rise and fall, according to the time elapsed, whether stationary or passing onward, within two hours and a half, or less than half a tide.

The tidal current lines show that even a less allowance is to be made for the change of current than for the change of tide; the difference in the change of current between Throg's Point and Fisher's island, along the middle of the sound, being of no practicable importance. Passing out of Long Island sound the tidal hours grow earlier, until off Block island that of Sandy Hook is again reached. The co-tidal line of Sandy Hook and Block island being the same, it is the struggle of the same tide through New York bay and the narrow East river, and obstructed Hell Gate, and through Fisher's island and Long Island sound, and to Throg's Point. The tidal currents meet near Throg's Point.

The lower part of Narragansett bay has the co-tidal hour 12 hours, nearly. Buzzard's bay has nearly the same co-tidal hour, the tide wave reaching the shore at nearly the same time all around the bay.

It would be impossible to give in a small compass a minute account of the tides of Martha's Vineyard and Nantucket sound. In general it may be said that as far as Holmes's Hole and Wood's Hole they resemble those of Block island sound, and afterwards those of Monomoy, at the eastern entrance; but this generalization is unsatisfactory without more details than there is space here to give. In these sounds take place the remarkable change of between three and four hours, the greatest change of our coast, dislocating, as it were, the times of high water at places south and west and east and north of Nantucket. The whole of this change takes place between the eastern entrance of Nantucket sound and the western of Martha's Vineyard, giving rise to quite a complex condition of both tides and currents, which it has occupied much time to unravel. The dominant co-tidal line of our coast, from Block island to Cape Cañaveral, is that of 12 hours of Greenwich time; that of our eastern coast, from Nantucket to Passamaquoddy, is, in general, 15 hours. Passing out of Nantucket sound coasters carry nearly the same co-tidal hour to Cape Cod, and thence vary their time about half an hour in passing to Boston, to Portsmouth, to Portland, or to Passamaquoddy. It has long been known that the tidal almanac for Boston might practically be used for eastern ports. Vessels from New York to Halifax, and New York to Europe, which keep outside, and should keep well off the Nantucket shoals, and off George's, as shown by the track on the chart, vary their co-tidal hour but little, keeping between the lines of 12 and $11\frac{1}{2}$ until quite well on their course, and beyond Cape Sable. The same rule will apply to their case as has been given for vessels between New York and a southern port.

APPENDIX No. 17.

Lecture on the Gulf Stream, prepared at the request of the American Association for the Advancement of Science. By A. D. Bache, Supt. U. S. Coast Survey.

By request of the association, at their last meeting at Springfield, I present a summary of the results of the Gulf Stream explorations made by the officers of the Coast Survey. The Gulf Stream is the great hydrographic feature of the United States coast, and no survey of the coast could be complete for the purposes of navigation without it. Hence the explorations have been early undertaken, and thoroughly carried on. But as it required peculiar means, and special adaptation in the officers to this line of research, and did not require a continuous survey, the work has been executed from time to time, as means and officers could be had, without interference with the more regular operations of the hydrography. An act of Congress which refers to this survey requires the immediate presentation of its results to Congress, and they have, therefore, been discussed as soon as procured, and have been given to the public.

This is the great sea mark of the coast of the United States, both Gulf and Atlantic, and its qualities as hindrances and aids to navigation require that the navigator should be well informed in regard to them.

In order to present an intelligible summary of the results obtained by the Coast Survey in the short time allowed for a lecture, it is necessary to condense the subject very considerably; to omit matters at all extraneous to the subjects in hand, and to confine myself to a brief and direct statement of the *means employed in examining the stream from its surface to its depths, the methods of studying the results, and of the results themselves.*

The temperatures in and near the Gulf Stream are among the most striking of its peculiarities, and therefore have formed one principal object of observation. It will be necessary, in order to bring the subject within limits, to confine myself chiefly at this time to the consideration of this class of facts, and to the results and laws connected with them.

I shall proceed, therefore, to consider the subject under the following heads:

I. The instruments for determining depths and temperatures, and for obtaining specimens of the bottom.

II. The plan of research.

III. The method of discussion of the results.

IV. The results, consisting of type curves, of the law of change of temperature, with depth at several characteristic positions. Type curves, showing the distribution of temperature across the stream, represented by two sets of curves, one in which the variable temperature at the same depth is shown, and the other in which the variable depth of the same temperature is represented. Upon the diagrams showing these latter curves the figure of the bottom of the sea is given where it has been obtained.

Discussion in regard to the cold wall, which is one of the most interesting features of the approach to the Gulf Stream.

V. The limit of accuracy of the results.

VI. The figure of the bottom of the ocean below the Gulf Stream.

VII. The general features of the Gulf Stream as to temperature.

These points are illustrated by diagrams, enabling the eye to follow the results as they are stated.

I. Instruments.

1. *For temperatures.*—The instrument for determining temperatures should fulfil the two conditions of registering its indications and of being unaffected by pressure. The common mercurial

thermometer, while it answers perfectly for the determination of temperatures at the surface, fails in both the conditions stated. The ordinary self-registering thermometer, or self-registering metallic thermometer in the watch form, as made by Breguet, Montandon, and Jürgensen, when provided with a suitable cover to protect it from pressure, answers a good purpose, and has been extensively applied in the course of the observations. As a rule, it is only the minimum temperature thermometers that must be used, as the temperatures decrease generally in descending. An ordinary self-registering minimum thermometer placed in a glass globe was successfully used by Commander Charles H. Davis and by Lieut. G. M. Bache. It has the disadvantage of taking the temperature slowly, and of being inapplicable below a certain depth. Small hollow cylindrical brass vessels, which were divided in two parts, closely fitting by grinding, and within which the Breguet thermometers of the watch form were placed, were an improvement upon the globe, as taking the temperature of the sea more rapidly; but, besides the difficulty of making the joint tight, they were crushed by the pressure at even moderate depths. The substitution of the globe for the cylinder extended the range of these instruments, but the thermometers were often crushed or injured by the access of the sea water to the interior of the globe. Six's self-registering thermometers, as bearing considerable pressure without injury, and without rendering the indications erroneous, and as requiring no case to enclose them, except to prevent breaking from accidental knocks in handling, are very useful. They are still favorites with many of the officers, though others complain of their great liability to derangement, especially if the mercury is not perfectly clean, when the mercurial column easily separates, and some skill is required to bring it together. These instruments are, from their cheapness, still furnished to the parties, and are used successfully at depths reaching about one hundred fathoms, and on occasions considerably lower. Keeping them in order requires the skill of an experimenter rather than that of an observer, and hence they do not satisfactorily fulfil the conditions of the problem. The metallic thermometer of Joseph Saxton, esq., of the United States Office of Weights and Measures, is based upon the coil form of that of Breguet. Two stout ribands of silver and platinum are coiled and carefully united with silver solder, the more expansive metal in the interior. A coil of gold, to which each is soldered, serves to prevent the tendency of the silver and platinum to separate. The lower part of the coil is fastened to a brass stem, which passes up through the axis of the coil, while the opposite end to that at which the stem is attached is firmly fastened to the base of a short cylinder, which keeps that end of the coil from turning, and so gives the whole motion of the opposite end of the coil to the stem, which in turning indicates the turning of the coil from the relative expanding or contracting of the metals composing it. In this short cylinder are the wheels which serve to magnify the motion of the coil, a hand upon the dial indicating the motion, and pushing before it a registering hand, moving with sufficient friction merely to retain its place when thrust forward by the index hand of the thermometer. These instruments are graduated by trial. The brass and silver portions receive a thick coating of gold by the electrotype process, to prevent the action of the sea water upon them. When kept clean by frequent washing in fresh water, and in good order, and frequently compared with the standards to guard against accidental derangements, these thermometers answer admirably all the required conditions. The length of the coil measured along its axis should not be less than six inches, as the interposition of wheels to magnify the motion should as far as possible be avoided. The water being all around the coil, which is a good conductor and has a low specific heat, the instrument readily feels the temperature of the part of the sea where it is exposed, and registers it to less than half a degree (say $0^{\circ}.2$) with certainty. The box which covers the coil and indicating part of the thermometer is merely to protect it from accidental injury, and is open so as to permit the sea water to pass freely through it. Sketch No. 19 gives a view of Saxton's metallic thermometer, and its various parts in detail. Although there seems no reason to doubt that this instrument is free from any effect from pressure, it was deemed desirable to try it actually by extreme

pressure, and a series of experiments made by J. M. Batchelder, esq., showed that at pressures less than that corresponding to 600 fathoms the effect was less than one degree, (.25 to 1°;) and at pressures from 600 to 1,500 fathoms the change amounted to little more than from 7° to 9° Fahr., the index returning when the pressure was removed. For great depths, the effects of pressure must be ascertained, as it is specific in each instrument, and probably chiefly depends upon some mechanical defect in the construction, as in the soldering.* The apparatus used in these experiments on the effect of pressure was a very ingenious one for testing hydraulic engines, by Mr. Thomas Davison, of the Novelty Iron Works of New York.—(Fig. No. 12, Sketch No. 20.)

2. *For depth.*—When the depth becomes considerable, the usual sounding line fails entirely to give it, especially if there is a current, and more especially if there is besides a counter current. The amount of "stray line" is variable. This subject has been ably examined of late years by Commanders Maury and S. P. Lee, Lieutenants Berryman, Brooke, and others of our navy, and by Commander Dayman and others of the British navy, and especially by Professor Trowbridge, of the Coast Survey, in his memoir read before the association ("Deep Sea Soundings, by W. P. Trowbridge, Assistant U. S. Coast Survey") at the meeting in Baltimore, and republished in the American Journal of Science and Arts, vol. xxviii, for the year 1858.

The use of Ogden's or Ericcson's leads to 100 fathoms is still continued by some of the officers of the survey. though at such depths nothing better than the common sounding line is, in fact, required. Massey's lead, with Woltman's wheel as an indicator, has been extensively used of late years. Mr. Saxton's indicator is more simple than Massey's, but acts upon the same principle. To remedy the defect of the turning of the cord of the lead line, two indicators are applied, one on each side of the axis. Professor Trowbridge's lead, modified somewhat from that described at the meeting of the Association in Baltimore, has recently been tried with good success by Lieut. Comg. Wilkinson in the last soundings across the straits of Florida for the telegraph to Havana. The most reliable observations heretofore made in the Coast Survey have been with Massey's indicator. The errors are not such as to affect the development of the laws of change at the moderate depths reached in most of the observations, and at great depths the changes are very slow. The new apparatus will have the advantage of saving a great deal of time, and therefore avoid inaccuracies from change of position during the sounding.

3. *For obtaining specimens of the bottom.*—The only satisfactory test of having reached the bottom of the sea at considerable depths being the bringing up of a specimen, this has been a subject of constant study with us. The different instruments invented by Lieutenant Stellwagen, Commander Sands, Lieutenant Craven, Lieutenant Berryman, Lieutenant Brooke, and other officers of our navy, are all in use for different kinds of bottom, and according to the preference given by different hydrographic chiefs. The one most commonly used in these explorations has been Lieutenant Stellwagen's invention—a cup placed below the sounding lead, covered by a valve of leather, which slides up the stem of the cup and opens when the lead is descending, closing when it is raised. The weight of the lead, and the turning of the cord generally, suffice to sink tho cup into the bottom, filling it; and when the valve is made to close tightly by a piece of flexible leather below the stiff disk, the specimen is not washed out as the lead is drawn up. In Commander Sands's sounding apparatus a spring keeps an outer cylinder over an opening in an inner hollow one, until it reaches the bottom, when the outer cylinder is forced upwards, and the opening at the side of the inner one, which, having a conical termination, penetrates the bottom, permitting a specimen of the bottom to pass in. On raising the lead the spring forces the outer cylinder over the opening, preventing the spe-

*Gulf Stream Explorations, Third Memoir; Proceedings Amer. Assoc. Adv. Sc., 13th meeting, Springfield, 1859; and Appendix No. 25, C. S. Report, 1859.

cimen from being washed out. The only very deep soundings being, as a general rule, in soft bottom, Sands's specimen cylinder is admirably adapted to that class of work.

II. Plan of the work.

The plan of the work was simple. The temperatures were to be ascertained at various depths, at different distances from the coast, on sections as nearly at right angles with the stream as practicable, the sections starting from some point well known in position. The temperatures were to be taken at distances diminishing as the changes of temperature were more rapid. So in regard to depth; the observations were to be multiplied in the strata of rapidly varying temperatures near the surface. So in regard to position, when the cold water near the coast was rapidly exchanging for the warm water of the Gulf Stream, the sections diminishing in distance as the source of the warm water was approached.

The vessel's position was determined with reference to some prominent point, Sandy Hook or Cape May, for example. The course run was perpendicular to the supposed axis of the stream, SE. Several positions were taken up in succession, and at each the temperature ascertained at the surface, at 5, 10, 15, 20, 30, 50, 100, 200, 300, 400, or 600 fathoms, or depths found to apply more satisfactorily, under the general rule, to the position and section. Having crossed the stream, any position found to be desirable could be assumed on returning, and the extreme position reached was verified by the return to the coast.

The summer season was selected for the standard observations for various reasons, but chiefly for two, namely, that the weather permitted more accurate work, and the phenomena were more likely to be those of equilibrium when the surface water was more slowly changing its temperature. Our little vessels could not, without considerable danger, be exposed to the roughness of the wind and water in the Gulf Stream in winter, and when we attempted comparative winter observations disappointment was often the result. The loss of one valuable officer and ten of his crew, and the extreme peril of another, in autumnal explorations of the Stream, has but too fully justified these precautions. The propriety of the selection of the summer for making the observations was completely proved by the success in determining the laws of temperatures.

These observations were but incidental to the hydrography of the coast, and hence were only prosecuted when means could be spared from other more pressing and regular parts of the work. It was only a favorable conjunction in regard to officers, means, weather, adaptation of vessel, and the like, which gave results even when attempted. Too much credit cannot be assigned to those who have succeeded in this laborious and perilous work, and their names have been kept in close connection with their results whenever and wherever brought before the public, and have been carefully preserved in the archives of the survey. Charles H. Davis, George M. Bache, S. P. Lee, Richard Bache, John N. Maffitt, T. A. Craven, Otway H. Berryman, B. F. Sands, and John Wilkinson, make up the list of our successful observers in this field within the last sixteen years. Their names you will see attached to the sections run by them on the general diagram of the Gulf Stream (Sketch No. 21) presented to you this evening. The first was run, in 1844, from Nantucket southward and eastward by Commander C. H. Davis, now the accomplished superintendent of the Nautical Almanac, and the last, in 1860, by Lieutenant John Wilkinson, from the Tortugas southeast to the coast of Cuba. The work still goes on perseveringly.

The number of sections run has been fourteen; the number of positions on these sections occupied three hundred; and the number of observations made for temperature thirty-six hundred. The limits below which the stream and the adjacent waters have been explored for temperatures are from latitude 23° N. to 41° N., and from longitude 83° W. to 66½° W.; from near Havana to near Cape Cod, and from the Tortugas to 9½° E. of Cape Henlopen. The

distance along the axis of the Gulf Stream to the most northeastern point in the North Atlantic measures nearly 1,400 nautical miles.

III. Method of discussion of results.

These have generally been discussed by diagrams; sometimes by analytical formulae. The former method is generally best adapted to the character and degree of accuracy and circumstances of the observations. The diagrams finally adopted, after trial, were chiefly of three different kinds: one for the discussion of the change of temperatures with depth; the two others for the change of temperature with position as well as depth. Of the first of these diagrams, Nos. 1 and 2 (Sketch No. 19) are specimens. The depths constitute the ordinates, and the temperature the abscissæ of a curve, showing the law of change of temperature with the depth. Upon the horizontal lines at the top of the paper the temperatures from ten degrees to ten degrees Fahr. are written, and on the vertical line at the side the depths. The separate observations being represented by dots, the curve is drawn with a free hand among them.

The next two classes of diagrams give the distribution of temperature across the sections; in the first, the temperature corresponding to the same depth; in the second, the depths corresponding to the same temperatures. In this latter the figure of the bottom is shown when ascertained. In both classes the distances from the cape, or headland, city, or inlet, which is the origin of the section, is marked, and the several positions occupied for observing, so that the abscissæ of the curve are the distances from the point of beginning. In the first, (see Diagram No. 4, Sketch No. 19,) the temperatures are marked on the vertical lines at the left side of the diagrams, the ordinates of the curve thus corresponding to temperatures. In the second, (see Diagram No. 9, Sketch No. 19,) the depths are similarly written, the ordinates thus corresponding to depths. The notes or legend shows in the first case to what depths the curves correspond, and in the second to what temperatures. The observations at each position being plotted according to its temperature or depth in the two classes of diagrams, the curve is drawn with a free hand among the points.

It should be observed that the discussion of each season's observation was, in general, made separately, and that the results of one, two, or three seasons grouped were announced separately, leaving to the new observations to confirm or refute the conclusions drawn. It is a remarkable fact that, with such difficulties in the way in the character of the phenomena to be observed—in the diversity of seasons and of observers—that the phenomena have always been readily deducible from the observations, and that the separate discussions have been confirmations, the following of the preceding; in fact, that the nature of the medium in which the work has been performed, in its relations to heat, has more than compensated for other difficulties, and that the results are more accordant than the elaborate ones obtained from the progress of temperature below the surface of the ground by the experienced and skilful observers who have made them. Few observations have been rejected in the whole series.

I need not notice special diagrams, which will be explained when your attention is called to them.

Where the character of the diagrams to be made had been definitively fixed, they were prepared under the direction of the chiefs of parties, so that I was relieved of the personal labor of representing the results. In the subsequent general discussions I was greatly assisted by Prof. Pendleton, U. S. N., and by Prof. W. P. Trowbridge, Assistant U. S. Coast Survey, who has made a general review of the whole of the results, preparatory to their publication in a volume of the Records and Results of the Coast Survey.

IV. Results.

I. *Type curves of law of temperature with depth at the most characteristic positions.*—The two most characteristic positions are in the cold current between the land and the Gulf Stream and in the axis of the stream itself.

(*a.*) Diagram No. 1, Sketch No. 19, is a specimen of the type curve in the cold current. The long tongue from the surface to about 50 fathoms in depth is the overflow of the warm water of the Gulf Stream, the temperature varying from 81° to about 55°. The temperatures in the mass of water from 50 fathoms down to 500 fathoms are just such as would take place in a mass of water heated by conduction from the surface; the law is that of a logarithmic curve in which the conducting power of sea-water is the modulous of the system.

A comparison of many of these curves with the logarithmic form showed that it was applicable to them within the limits of the probable error of the observations. Taking the warm stratum from the Gulf of Mexico above, and the cold polar stratum below, the mass of the water is heated by conduction. The bottom of the sea has not been reached under the axis of the Gulf Stream north of Cape Lookout, on the North Carolina coast.

This form of curve was deduced in 1844 from the observations of Commander Charles H. Davis, and was the first discovery made in connection with the then recently commenced systematic exploration of the Gulf Stream by the Coast Survey.

(*b.*) Nos. 2, 3, and 3 *bis*, Sketch No. 19, are specimens of the type curve in the Gulf Stream, taken from the sections off Cape Henry, Cape Hatteras, and Charleston, being characterized by the comparatively short beak or projection, and the persistence of the higher temperature to great depths, as 55° to 425, 550, 450 fathoms, giving the peculiar shape to this curve between 50 and 500 fathoms.

II. *Type curves of distribution of temperature across the stream.* (*a.*) *Curves of temperature at the same depths.*—The sections made are the following, beginning the enumeration at the Gulf of Mexico: 1. Tortugas to Havana. 2. Sombrero key to Salt key. 3. Carysfort L. H. to Cuba. 4. Cape Florida to Bemini. 5. Off Cape Cañaveral. 6. Off St. Augustine. 7. Off St. Simon's, Georgia. 8. Off Charleston. 9. Off Cape Fear. 10. Off Cape Hatteras. 11. Off Cape Henry. 12. Off Cape May. 13. Off Sandy Hook. 14. Off Cape Cod, being, on the average, one to each hundred miles along the axis of the stream. These are marked on the general diagram, (Sketch No. 21,) the names of the explorers being stated in the column which gives the point of origin of each section.

The Sandy Hook curves, Nos. 4 and 5, (Sketch No. 19,) are among the best of the type curves of temperature at the same depth, though among the earliest determined. The overflow of the Gulf Stream into the long spur occupied by the cold current between it and the shore, mixing in a degree with the cold water, is well shown by the curves (*a*, *b*, and *c*) at the surface, 5 and 10 fathoms, and the still greater admixture with the cold water at 20, 30, and 50 fathoms, (*d*, *e*, *f*.) The whole space from the shore to 240 miles is occupied, however, with comparatively cold water. Then is met the sudden rise to the Gulf Stream, shown especially below 50 fathoms, and termed so appropriately by Lieut. Geo. M. Bache the "cold wall," that navigators have not hesitated to receive the term into use. Next the hot water of the Gulf Stream, rising to a maximum of 82°, then falling to a minimum of 80°, rising to a second maximum of 81¼°, falling to a second minimum of 78°, and rising from this towards a third maximum. With these results the curves at 5 and 10 fathoms, and those at 20, 30, 50, 70, 100, and 150 fathoms, agree, and with characteristic differences those of 200, 300, 400, and 500 fathoms.

The cold wall at 20 fathoms shows a rise of 19° in 25 miles, three-quarters of a degree to a mile, and at 200 fathoms of 16° in the same distance. At the surface it is nearly 8° in 50 miles. The cold water between the Gulf Stream and the shore has two well-marked maxima and two minima in it, of which one seems to correspond in position to the sudden deepening of

he water 100 miles from Sandy Hook, as shown by the Coast Survey off-shore chart between Gay Head and Cape Henlopen.

These results are more distinctly seen by grouping the curves into natural groups and taking the mean of their indications. Diagram No. 5 (Sketch No. 19) gives the group of six curves from the surface to 30 fathoms, of four curves from 40 to 100 fathoms, both inclusive, of 200, 300, and the single curve at 400 fathoms.

Similar groups are shown on Diagram No. 6 (Sketch No. 19) from Cape Henry, the cold wall, three maxima of temperature and three minima being very distinctly seen. The results of three different explorations of this section by three different officers in three different years are shown upon the same diagram. The coincidence of result could hardly be better. The average of the whole of the observations is shown on No. 6 *bis*, (Sketch No. 19.)

The cold wall here gives a change of $22\frac{1}{2}°$ in 50 miles from the curves between 0 and 30 fathoms, and 13° in 50 miles in the mean of 200, 300, and 400 fathoms.

The average of the three years comes out beautifully on Diagram No. 6 *bis*, (Sketch No. 19.)

The Charleston curves are shown upon No. 7, (Sketch No. 19.) They are less regular than those just given, for reasons which will appear when I come to speak of the second class of diagrams.

The conclusions deduced from the examination of all the sections between Cape Florida and Sandy Hook is, that the Gulf Stream is divided into alternate bands of hot or warm and cool or cold water, the most distinct of which is that containing the axis of the Gulf Stream.

That between the stream and the coast there is a fall of temperature so sudden that it has been aptly called the cold wall, less distinct at the surface, and when the overflow from the Gulf Stream passes furthest towards the shore, but still distinctly marked even at the surface.

Navigators have noticed these changes of temperature, and have supposed themselves at each occurrence of warmer water to be in the hottest water of the stream, and so have been greatly embarrassed, and have deemed the phenomena and limits of the Gulf Stream to be very irregular.

The cold water between the Gulf Stream and the shore has also bands less regular than those beyond the axis of warmer and cooler water.

The intrusive cool water in the Gulf Stream on the Sandy Hook section was distinctly recognized in 1846 by Lieut. Geo. M. Bache, who, from the facts observed, supposed it to represent a division of the warm water of the stream into two branches.

Passing through the Straits of Florida, between the keys and reefs and the coast of Cuba, we have, after going beyond Cape Florida, a different type curve. The cold wall is less distinctly marked, and the rise of temperature is less marked. It rises, however, to an axis near the coast of Cuba. Throughout the length of the strait there is but one maximum of temperature, and the bands belonging to the Atlantic regimen do not occur in the straits.—(See Diagrams Nos. 3, 4, 5, 6, Sketch No. 20.) The cause of this change of regimen will be seen in presenting the other form of diagram.

(*b.*) *Curves of depths at the same temperature.*—I have selected curves from the southern portions of the work partly because the bottom has been struck in the sections, and the diagram shows its sections as well as those of the stream, and partly to show how fully the deductions in regard to the divisions of the stream apply to these as well as to the more northern sections. The Charleston section of Lieut. Maffitt is given on Diagram No. 9, Sketch No. 19. The surface curve, notwithstanding the disturbance by a storm, shows the cold wall, (see also Diagram No. 7,) the axis and two other maxima; the corresponding minima, a maximum within the cold current, which is not, therefore, as has been supposed, cut off at Hatteras, the curve of 72° reaching to the coast, and 77° nearly reaching it. The Cape Florida diagrams (Nos. 3 and 7, Sketch No. 20) give two maxima, with indications of a third, and the corresponding minima. The cold wall cannot be recognized upon it probably for the want of one or two more positions.

The form of the bottom delineated on these two sections, namely, the Charleston and Cape Florida sections, is remarkable, and applies to the sections between them as far as explored.

First is a gentle slope; then a sudden descent; a second steep pitch to a considerable depth; a range of hills; a valley, and a second range.

The correspondence of these features with the bands of temperature is plainly marked. The cold water lies in the valleys, and passing along the bottom rises upon the tops of the hills. The discovery of this range of hills was made at nearly the same time by Lieut. Maffitt on the Charleston section, and by Lieut. Craven on the St. Simon's section. Diagram No. 9, Sketch No. 19, shows this connection in a very striking manner, as does also No. 7, Sketch No. 20, and the figure of the bottom of the Straits of Florida shows why there are no bands formed prior to passing Cape Florida: in other words, why the regimen of the stream is different in the straits and in the Atlantic. In the straits we see (No. 9, Sketch No. 20) that after leaving the United States shore, and the comparatively flat surface extending to the reef, there is a rapid descent towards the Cuban side of the strait, the axis of the Gulf Stream being found in the deep hollow of that side of the strait. These results, with a more elaborate discussion of them, were presented at the last meeting of the Association. It would seem from the configuration of the bottom that the cold stream at the bottom of the Straits of Florida divides, one portion passing to the north and west into the Gulf of Mexico, and the other around the western end of the Island of Cuba. That the polar stream still occupies the bottom of the strait is shown by temperature of 35° Fahr. being reached at 600 fathoms from the surface off Havana.

Do these bands correspond throughout their length to the form of the bottom of the sea? This is not yet made out, many as have been the attempts to reach the considerable depths off the more northern sections. Three officers have attempted to sound out the Cape Cod section, but the cold wall is all that has been reached thus far. The range of hills nearest the coast has been traced from the coast of Georgia, by Commander Sands, to off Cape Lookout.

3. *The cold wall.*—The cold wall extends, with varying dimensions and changes of its peculiar features, all along the coast where the stream has been examined. A diagram showing the features of the cold wall on the various Atlantic sections, and those of the Straits of Florida, is given in No. 10, Sketch No. 19; and Table No. 1 shows the distance of the cold wall from the coast, and the dimensions of the Atlantic bands of the Gulf Stream.

TABLE No. I.

Distance of the cold wall from the shore, and widths of the several bands of cold and warm water of the Gulf Stream, measured on the lines of the section.

Names of sections.	Distance of cold wall from shore, in miles.	Width of first max. or warm band.	Width of second min. or cold band.	Width of second max.	Width of Gulf Stream proper.	Width of third min. or cool band.	Width of third max. or warm band.	Width of fourth min. or cold band.
Sandy Hook	240	60	30	37	127	60	50	Indef.
Cape May	125	55	30	40	125	70	65	70
Cape Henry	95	45	32	47	124	80	60	50
Cape Hatteras	30	47	25	45	117	37	75	70
Cape Fear	60	30	20	37	87	30	60	25
Charleston	62	25	15	30	67	26	35	....
St. Simon's	87	25	13	20	58	25	25	....
St Augustine	70	20	13	12	47	22	20	....
Cape Cañaveral	35	20	....	....	35	14	12	....
Cape Florida	10	25	....	....	25	5	....	....

NOTE.—The widths of the bands beyond the 2d maximum and north of Cape Hatteras are somewhat indefinite.

The table shows that at Cape Florida and Cape Hatteras the cold wall is nearest to the coast. The distance of the axis of the stream from its coast will be found by adding half the numbers in the second column to those in the first column. It is obvious from these numbers, when taken in connection with the longitudes of the points where the sections originate, that the earth's motion is not the sole determining cause of the direction of the axis of the stream, a result which a more elaborate investigation of the movements from parallel to parallel confirms. In the portions of its course between Cape Florida and Mosquito inlet ($3\frac{1}{4}^\circ$ of latitude) the curve is actually slightly to the westward.

The table shows a width in the Gulf Stream proper along the Atlantic coast of from 25 miles off Cape Florida to 127 miles off Sandy Hook. The warm water at, say, fifteen fathoms varies from 30 to 150 miles in width. The stream widens each way from Cape Florida. These several divisions of the Atlantic stream lose a portion of their distinctness as we pass northward and eastward, the stream widening.

V. Limit of accuracy of the determinations.

There are two modes by which the limits of accuracy of these results may be tested, by one of which their permanency is also tried. In this latter mode the sections are run over in different years, or in the same year, by different officers, so as to connect the observations of one year with those of the next, or of one officer with those of another. Table No. II shows that the relative results are reproduced from year to year with less variability than those of the mean temperature of the section, and hence the permanency of the bands, and the possibility of observing them with the requisite precision must be admitted. On the Cape Henry section, which was explored three times, the position of the cold wall and of the axis of the stream were reproduced within $5\frac{1}{2}$ miles, and those of the succeeding points of maximum and minimum temperatures within $7\frac{1}{2}$ miles. As the positions at sea are liable to an uncertainty of some three to five miles, it must be admitted that the permanency of the bands and the accuracy of the observations of them are fully found. The Cape Henry section was run over by Lieuts. George M. Bache, S. P. Lee, and Richard Bache; the Hatteras section by Lieuts. Richard Bache and J. N. Maffitt; and the Charleston section by Lieuts. J. N. Maffitt and T. A. Craven.

TABLE No. II.

Table showing the probable uncertainty in the determination of maximum and minimum points by running the same section over in different years by different observers.

CAPE HENRY SECTION.

Dates and names of observers.	Mean distances from the shore, in miles, from the curves representing the groups.						
	Cold wall or first min.	Axis or first max.	Second min.	Second max.	Third min.	Third max.	Fourth min.
Lieut. G. M. Bache, 1846	93	135	187	218	260	320	369
Lieut. S. P. Lee, 1847	91	146	185	215	291	337	378
Lieut. R. Bache, 1848	97	146	180	197	287	328	370
Means for three years	94	142	184	210	279	328	372
Probable error for each year	5.85	4.27	2.42	7.62	11.31	5.71	7.18

TABLE No. II—Continued.

CAPE HATTERAS SECTION.

Dates and names of observers.	Mean distances from the shore, in miles, from the curves representing the groups.						
	Cold wall or first min.	Axis or first max.	Second min.	Second max.	Third min.	Third max.	Fourth min.
Lieut. R. Bache, 1848	....	90	134	162	214	276	355
Lieut. J. N. Maffitt, 1853	....	75	125	157	211	256	322
Means for two years	....	82	129	159	212	266	338
Probable error for each year	....	6.4	4.3	2.4	1.5	15	16
Means for both sections	5.85	5.3	3.4	5.0	6.4	10.4	11.6

Average uncertainty of maxima and minima .... 6.9 miles.
Average uncertainty of cold wall and axis .... 5.5 "
Average uncertainty of all the other points .... 7.4 "

The other mode of testing the result is by the comparison of the remarkable points in the different sections, each one belonging to a different position, and therefore being entirely independent of the other in its determination. It is established as a general law that this cold wall and axis of the hottest water change their position from the surface to the depth of six hundred fathoms slowly and by an ascertained progression, and that the succeeding maximum and minimum points are at the same distance from the shore, nearly, at different depths, or in a vertical line at all the different depths. The positions of these points, as shown by the observations at different depths, became thus the test of the permanency of their positions and of the accuracy with which they have been ascertained. The Table III gives the probable error of the mean of the determinations of each point including the cold wall minimum, the axis maximum, and the successive minima and maxima to the fourth minimum, inclusive. These results show that the cold wall minimum is ascertained, on the average, within 0.83 mile, the axis maximum within two miles and a half; the second minimum within two miles and a half; the second maximum and the third minimum, and third maximum, within four miles; and the fourth maximum within eight and a half miles; all being satisfactory except the last, which, of course, is in reality loosely defined. The Hatteras result for the axis of the stream makes the probable error considerably larger than it would otherwise be, probably from the fact that the proximity of the bottom of the sea makes the result less permanent than in the other cases. Without this result the mean probable error would be 1.1 mile.

TABLE III.

RECAPITULATION.

Showing the value of the probable error of determination of the bands for each section, and the average of the whole.

Sections.	Probable errors.						
	1st min.	1st max.	2d min.	2d max.	3d min.	3d max.	4th min.
Sandy Hook	....	.75	.00	3.94	7.99	....	....
Cape May	.82	1.25	2.54	1.57	....	4.03	4.87
Cape Henry, (3 years)	.84	.61	.55	1.70	1.06	.94	3.42
Cape Hatteras, (2 years)	....	6.77	6.36	9.31	5.69	6.23	....
Cape Fear	....	1.25	....	....	2.98	3.49	13.37
Charleston	1.25	1.57	.72	2.09	2.40	.82	....
St. Simon's	.00	.74	1.27	.41	....	....	....
St. Augustine	.52	.51	.44	.44	.55	....	....
Cape Cañaveral	.95	1.69	.39	....	....	....	....
Mean probable error	.83	2.49	2.49	4.00	4.01	3.71	8.45

While these results are so permanent the mean temperatures of the sections change considerably from year to year. The average temperature between the surface and 400 fathoms beyond, or outside of the cold wall on the Sandy Hook section in 1846, was as high as that on the Cape Henry section in 1848, and that on the Cape Fear section in 1853, and within a degree of that of the St. Augustine section in 1853, while the Cape Hatteras section in 1848 and 1853 differed two degrees in mean temperatures. Again, the temperatures from the surface to 30 fathoms just below the axis of the stream in the Sandy Hook section in August, 1846, was either as high as or higher than those on the Cañaveral section in June, 1853. In general, the Cape May section in 1846, and the mean of the Cape Henry sections of 1846, 1847, and 1848, are warmer at the same depths than the sections south of it were in 1848 and 1853.

These results show that there are great changes in temperature from year to year, and probably from season to season. Some progress has been made in connecting these results in a general way with the changes of weather in the Gulf of Mexico.

The depth at which the results are easily determined, and where they are characteristic and as permanent as the phenomena permit, is thirty fathoms.

VI. Figure of the bottom of the sea below the Gulf Stream.

We have seen that in cross section there is a great resemblance in the bottom of the sea off our coast to the region of land more removed from the coast line in the interior. The top of the first range of hills (see Diagram No. 9, Sketch No. 19) is 1,500 feet above the valley to the eastward of it, distant 12 miles, and the top of the second range 600 feet above the same valley, distant 15 miles. The first slope is 125 feet and the second is 40 feet to the mile. The bottom of the sea from the Tortugas section to that of Cape Florida rises from 800 to 325 fathoms, and from the same point descends in passing northward and eastward. The Cape Florida section should then present a ridge of comparatively cold water, since the division into

bands should apply along the stream as well as in the direction of its cross sections. The temperature of 40° is in fact reached on that section at 300 fathoms, and, as well as can be judged from the results in the separate sections, there are divisions of this sort. The diagram (No. 2, Sketch No. 20) shows where the curve of 50° and 45° are found upon the different sections, and indicates a rise on the Charleston section and a sharp descent from Charleston to Cape Fear.

VII. General features of the Gulf Stream.

Upon the general diagram now presented to the members (see Sketch No. 21) the general features of the Gulf Stream are represented from the Tortugas to the Cape Cod section. Passing along the Cuban coast, the temperature in June was found to be about 84°, or 8° above the mean temperature of Key West, as given by the surgeon general's report. The current here is feeble, but sufficient to cause it to be sought by sailing vessels working to windward, and even by steamers.

Issuing from the Straits of Bemini, the stream is turned northward by the land, which confines and directs its course. Its effective velocity is not derived from difference of temperatures, as the observations abundantly show, the greatest relative differences being, in fact, crosswise of the stream. The direction is here a little west of north, and the velocity is from three to five miles per hour. The temperature bands now begin. The bottom of the sea, which was one slope and counter slope across the Florida straits, is here corrugated. The depth, instead of being unfathomable, as has heretofore been supposed, is but 325 fathoms, in which the two currents from the poles at the bottom and from the Gulf at the top must pass each other; while the surface water is above 80°, that near the bottom is as low as 40°. The stream just north of Mosquito inlet begins to bend to the eastward of north, and off St. Augustine has a decided set to the eastward. While flowing thus onward the warm water seeks the sides of the channel overflowing towards the coast of Florida and towards the Bahamas, but not as rapidly as it leaves the north. Between St. Augustine and Cape Hatteras the set of the stream and the trend of the coast differ but little, making five degrees of easting in five degrees of northing. At Hatteras it curves to the northward, and then runs easterly, making about three degrees of northing in three of easting. In the latitude of Cape Charles it turns quite to the eastward, having a velocity of one and one mile and a half the hour.

That this curve follows the general sweep of the coast under water appears most probable; the coast line, the curve of 100 fathoms, and the ranges of hills discovered by Lieuts. Maffitt and Craven all seem to indicate it. That the direction of the stream is given in a general way by the configuration of the bottom of the sea it is hardly possible to doubt, while admitting that it receives modification from other and perhaps more general causes. The after progress of this mighty stream, and of its branches if it does divide, remain yet to be traced, and so also its heading in the Gulf of Mexico.

I forbear to mingle doubtful speculation upon causes with the inductions in regard to temperature which it has been the object of these observations to supply, and of this lecture to bring to your notice.

APPENDIX No. 18.

Report to the Superintendent by Assistant L. F. Pourtales, in charge of the field and office work, relating to tidal observations.

COAST SURVEY OFFICE, *October* 1, 1860.

SIR: I have the honor to submit the following report on the field and office work performed by the tidal party under my charge during the past year.

Field-work.—The permanent stations at which the tides have been observed for a long period are the same as in former years: Boston, New York, Old Point Comfort, Charleston, and Fort Clinch, Fla., on the Atlantic coast, and San Diego, San Francisco, and Astoria, on the Pacific coast. To these may be added Eastport, Me., and Tortugas and Pensacola, Florida, which, although not intended to be kept up as long as the other permanent stations, will still be in operation for several years. These stations are all supplied with self-registering tide-gauges, with the exception of the one in Boston. The results obtained have generally been satisfactory. The most complete sets are those of Boston, Tortugas, San Diego, San Francisco, and Astoria. At the other places the interruptions to the series are chiefly to be attributed to the insufficient stability of the wharves on which the clocks of the gauges rest. Experiments have been directed to try the effect of placing the self-registering apparatus on solid land, and to communicate with the float-box by means of a wire enclosed in a tube. The results have not yet been reported. Heretofore the self-registering observations were found impracticable at the northern ports during the winter, on account of ice forming in the float-box. At the suggestion of Assistant H. Mitchell, the gauge at Eastport was kept at work successfully by covering the surface of the water in the float-box with a layer of a few inches of kerosene oil. This expedient will be applied next winter at all the stations at which it may be necessary. An improvement, first suggested by Mr. S. Walker, has been introduced by Mr. Saxton in the last tide-gauge constructed. It consists in making the part of the receiving and delivering rollers on which the cords of the weights are wound of a conical form, so that the power of the weight on the receiving roller increases as the paper accumulates on it, and decreases on the delivering roller as its effective diameter diminishes by the delivery of the paper. The same weight operates both rollers.

The stations on the Western Coast have been continued under the efficient supervision of Lieut. G. H. Elliot, U. S. Engineers.

Of temporary stations, the one at the Washington navy yard is still in operation, under the charge of Mr. Donn, of this division. The series is quite sufficient for ordinary purposes, but the gauge is sometimes found of use in training new observers.

After Mr. Würdemann's death the charge of the stations in the Gulf of Mexico was intrusted to Mr. A. C. Mitchell. His first action, under your instructions, was to remove the tide-gauges from Charlotte harbor, Egmont key, and Cedar keys, Florida, and to establish four new stations at St. Mark's entrance, Dog island, Cape St. George, and St. Vincent's island, (west entrance to St. George's sound.) They were set up near to each other for the purpose of investigating the change from the semi-diurnal to the diurnal type, which occurs in that region. After a few months it was found that the stations at Dog island and Cape St. George might be dispensed with, as the change from one type to the other was very gradual. Those two gauges have therefore been removed lately to the Southwest Pass of the Mississippi and to Last island, on the coast of Louisiana. The performance of those gauges has been quite satisfactory.

We are again indebted to S. T. Abert, esq., civil engineer of the Warrington navy yard, for another year of excellent self-registering observations, taken at that place under his care.

A self-registering tide-gauge established at Cape San Lucas, Lower California, by Mr. Xantus, under the direction of Lieut. Elliot, has labored under great difficulties from the unfavorable location at which it was first erected. The water was not deep enough, and the float-box was sanded up at every gale. The low waters observed are therefore very defective.

The uncertainty and slowness of correspondence with the observer made it very difficult to remedy the evil. This gauge has lately been reset in a more favorable location.

All the tidal stations had, at the beginning of the year, their sets of meteorological instruments made more complete. Plottings of the observations have been communicated to the meteorological department of the British Board of Trade. I would especially call your attention to the very full set of observations furnished by Mr. Wilson, the observer at Astoria, Oregon.

The following table contains a list of the observations received during the year. The tidal observations taken by hydrographic parties for the reduction of soundings are not included:

List of tidal observations received during the year ending September 30, 1860.

Section.	Name of station.	Name of observer.	Kind of gauge.	Stations, permanent or temporary.	Time of occupation.		Total No. days.	Remarks.
					From—	To—		
I.	Eastport, Me	G. B. Vose	S. R.	Permanent.	Jan. 9, 1860	Sept. 30, 1860	266	
	Boston Dry Dock	T. E. Ready	Staff.	...do...	Oct. 1, 1859	...do...	366	
II.	Governor's Island, N. Y	R. T. Bassett	S. R	...do...	...do...	Dec. 29, 1859	90	Observations made at Brooklyn during the cold weather.
	Do	...do	..do..	...do...	Apr. 7, 1860	Sept. 30, 1860	176	
	Brooklyn, N. Y	...do	Box..	...do...	Oct. 1, 1859	...do...	100	Day observations only during summer.
III.	Old Point Comfort, Va.	M. C. King	S. R.	...do...	...do...	...do...	366	
	Washington Navy Yard, D. C.	Samuel Walker	..do..	Temporary.	...do...	Nov. 19, 1859	50	More than a month lost by freezing in winter.
	Do	John W. Donn	..do.	...do...	Nov. 20, 1859	Sept. 30, 1860	316	
V.	Charleston, S. C.	Wm. R. Herron	..do..	Permanent.	Oct. 1, 1859	...do...	366	
VI.	Fort Clinch, Fla	J. A. Walker	..do..	...do...	...do...	...do...	366	
	Tortugas, Fla	H. Benners	..do..	Temporary.	Sept. 2, 1859	Sept. 1, 1860	366	
	Charlotte Harbor, Fla	G. W. Maslin	..do..	...do...	Aug. 3, 1859	Oct. 20, 1859	79	
	Egmont Key, Fla	C. Keyser	..do..	...do...	Sept. 1, 1859	Nov. 12, 1859	73	
VII.	Cedar Keys, Fla	A. Steele	..do..	...do...	Sept. 2, 1859	Nov. 2, 1859	62	
	St. Mark's, Fla	P. H. Donegan	..do..	...do...	Dec. 1, 1859	Sept. 1, 1860	276	
	Dog Island, Fla	....	..do..	...do...	Dec. 14, 1859	Jan. 18, 1860	36	
	Do	D. M. Hodges	..do..	...do...	Jan. 21, 1860	June 14, 1860	146	
	New Inlet, Fla	G. W. Maslin	..do..	...do...	Jan. 8, 1860	June 22, 1860	167	
	St. Vincent's, Fla	C. Keyser	..do..	...do...	Jan. 13, 1860	July 25, 1860	195	
	Do	G. W. Maslin	..do..	...do...	July 26, 1860	Sept. 1, 1860	38	
	Warrington Navy Yard, Fla.	S. T. Abert	..do..	...do...	Aug. 19, 1859	Sept. 8, 1860	386	
VIII.	Southwest Pass, La	C. Keyser	..do..	...do...	July 30, 1860	Aug. 23, 1860	25	
	Last Island, La	Peter Wilson	..do..	...do...	July 12, 1860	Aug. 31, 1860	51	
X.	Cape San Lucas, Lower Cal.	J. Xantus	..do..	...do...	Apr. 30, 1859	Apr. 17, 1860	354	Many low waters lost.
	Do	...do.	Box..	...do...	Apr. 18, 1860	May 9, 1860	21	
	Do	...do.	S. R	...do...	May 10, 1860	June 17, 1860	39	
	San Diego, Cal	A. Cassidy	..do..	Permanent.	Aug. 1, 1859	July 1, 1860	336	
	Fort Point, Cal	H. E. Uhrlandt	..do..	...do...	...do...	...do...	336	
XI.	Astoria, Ore	Louis Wilson	..do..	...do...	...do...	...do...	336	

Office-work.—The following persons are now employed in this division: R. S. Avery, J. Downes, J. W. Donn, Ch. Balmain, J. R. Gilliss, M. Thomas, and S. D. Pendleton. Sub-Assistant C. Fendall, and Messrs. J. Gilliss, L. M. Johnson, and B. H. Todd, were temporarily attached to it for short periods of time.. The details of dates of reporting and of detachment will be found in my report to the Assistant in charge of the office.

Mr. Avery has been employed on a revision of some of the reductions of tides at permanent stations. He has also made a partial discussion of the anomalous tides of Tahiti from observations obtained from the French authorities of that island at the solicitation of Captain J.

Rodgers, U. S. N., some years ago. He was also occupied in reducing the decomposed tides from the stations on the coast of Florida, and other miscellaneous duties. During the period of my absence from the office last summer he had charge of this division.

The large amount of work required to bring up to date the graphical decomposition of the tides observed on the coast of Florida and to keep pace with the observations, has engaged the whole time of Messrs. Downes, Balmain, and J. R. Gilliss, with occasional help from others. The set, "Cape Florida, Indian Key, Key West, and Tortugas," was finished several months ago. The set, "Tortugas, Charlotte Harbor, Egmont Key, and Cedar Keys," is nearly finished, and the set from the new stations now occupied is but little behind the observations. Mr. Downes made also the plottings of meteorological observations alluded to above.

Mr. J. W. Donn has attended to the reading off of the sheets from the self-registering tide-gauges, except those of the Western Coast, which were read off in San Francisco by H. E. Uhrlandt.

Mr. Donn has also kept the register of the observations, received and acknowledged the receipt to the observers, and, besides, has had charge of the self-registering tide-gauge at the Washington navy yard.

Most of the ordinary reductions have been made by M. Thomas and S. D. Pendleton.

Very respectfully, your obedient servant,

L. F. POURTALES,

Assistant U. S. Coast Survey, in charge of Tidal Division.

Professor A. D. BACHE, LL.D.,

Superintendent U. S. Coast Survey.

APPENDIX No. 19.

Report of Capt. W. R. Palmer, U. S. Topographical Engineers, Assistant Coast Survey, in charge of the office, and sub-reports of the chiefs of office divisions.

U. S. COAST SURVEY OFFICE, *October* 4, 1860.

DEAR SIR: In conformity with the regulations which require the Assistant in charge of the office to present to the Superintendent of the Coast Survey an annual report of the operations and progress of the work executed in this office, I have the honor to submit the following report:

The duties of each division of the office, and the occupations of each employé, are fully shown in the accompanying sub-reports of the chiefs of divisions.

The office-work of the survey, having for its object the highly important part of reducing the work of the field parties to the forms necessary to bring the results within the reach of the public in the shape of finished charts, &c., of the most accurate and reliable character, its organization, duties, and labors, have always demanded and received constant care and watchfulness.

As new discoveries are made, new facilities afforded, from whatever sources they may be derived, it is essential that they be rendered available whenever the interests of the survey are thereby advanced, especially when rapidity of execution, increased economy, and accuracy can be attained.

In the Computing Division the highest mathematical talent is requisite, in order to reduce, by the most approved methods, the geodetic observations upon which the charts are based.

In the Drawing Division years of experience and special qualifications have always been required for the accurate and minute delineations necessary for the use of the engraver. The Superintendent is aware of the great difficulty of obtaining first class engravers. The care bestowed upon the critical examination of their labors demands and receives unwearied attention; the great expense of engraving, in the best style of the art, is also well known; and had it not been for the discovery of the electrotype process, and its prompt introduction and

improvement in the Coast Survey office, the annual expense of engraving would have rendered it impossible to have produced more than a small proportion of the finished charts that have been issued within the last few years.

Especial attention has now been devoted, for more than a year past, to improving the process of reducing the original field sheets by means of photography, in order to insure further rapidity, economy, and accuracy in the work of the Drawing and Engraving Divisions. It was for a long time doubtful whether photography could be successfully applied in reducing original drawings from a large, such as a $\frac{1}{10000}$, to a smaller, as an $\frac{1}{80000}$ scale, the photograph preserving at the same time the just proportions and distinctness of the original. These doubts have, after much labor and study, been entirely removed; and thus the means have been found by which a very great saving of time and labor may be effected. Heretofore these laborious reductions have been made by hand, requiring months of labor on the part of the most skilful draughtsman, to produce results which are now effected with greater accuracy in a few days. It might be supposed that the reduced drawing thus obtained at comparatively small labor and expense was now complete, and could be placed at once in the hands of the engraver, thus securing at one operation the advantages that have been referred to; but it was soon seen that the labors of the *engraver* might be lessened and facilitated by resorting to a modified system, which it may be well to explain in detail. In the process of engraving from a finished drawing by hand reduction much time is consumed in determining and selecting the true outlines; in this a sound judgment and considerable acquaintance with and knowledge of all topographical features is required; and even when an engraver possesses these qualifications there is a great probability of some errors occurring from the confusion occasioned by such a mass of minute details. The modified practice now adopted is to make in the Drawing Division a tracing of the general outlines of the original sheet; this tracing is sent to the Photographic Division, where three photographs are taken, two on the reduced scale required, one of them upon glass, the other upon paper; the third photograph is made upon paper of double the scale of the other two, to enable the engraver to see more readily and distinctly the topographical details. The photographs are returned to the Drawing Division, the first merely for verification; which done, it is sent to the Engraving Division, when every line, as it is seen in the reduction, is at once entered in the copper; thus far the work of the engraver is almost a merely mechanical process. Upon the two paper photographs the topographical features are represented in the Drawing Division by conventional colors, in accordance with special rules. The colored photographs, after having been verified, are taken to the engraver, who fills in the outlines already engraved by following strictly the topographical features represented by the colors; as it is necessary in this process to use a separate system of signs applicable to the engraver's art for representing these different topographical features, he is furnished with samples of each feature, in accordance with the special rules adopted by the Superintendent. Here again a saving of labor is effected; for by the former system the draughtsman was obliged to fill in the *whole sheet* with these topographical details, the engraver merely making a copy of the drawing, and constantly repeating the *identical strokes* of the pen of the draughtsman; this double work is now avoided, as is clearly seen. I present the foregoing as a general sketch, or explanation of the process now used; variations from this system are necessary in some particular cases, as when the different features change suddenly, or when the locality is one of complex contour, when, in addition to the coloring, the proper conventional signs, the hachuring of the hills, &c., must be indicated upon the photographic print, by pen-work in ink, to prevent confusion or mistake, and further facilitate the labor of the engraver.

The advantages of the use of photography in this office, as I have described it, are three-fold:

First. The increased accuracy attained in the reductions; for by using the photograph upon the glass the effects of the shrinkage of the paper and other sources of error incidental to hand reduction are avoided.

Second. The increased rapidity with which the office is enabled to issue the results of the work.

Third. In the saving of expense.

The experience already gained shows conclusively that a great saving of time results from this process. Formerly the engraving of the chart was often delayed until the finished drawing was completed, whereas now the engraver may begin his work the moment the outline of a single field sheet is given to him; other parts will always be finished before he is ready to commence upon them.

The want of facilities like these, and the fear of incurring too great an expense, have been the chief reasons why the Engraving Division has always been so much in arrears; and in order to bring up the back work, it is a measure of true economy to at once increase and strengthen this important division of the office. The value of the maps is enhanced, in my judgment, if they are given to the world in the least possible time (compatible with the requisite accuracy) after the field-work has been completed.

I do not think sufficient data exist to enable me to give anything like an accurate estimate in figures of the amount of money saved by means of photography. It is estimated in the office at about 33 per cent. upon the expenditures of the Drawing and Engraving Divisions; but the processes have not been long enough in operation to enable me to verify this. I am certain that the same annual expenditure in the Drawing and Engraving Divisions enables the office to complete the maps at least 33 per cent. faster than heretofore.

The Engraving Division should, I think, be increased at this time to an extent which would insure the completion of our first class charts, &c., in one-half the time they have heretofore required; and this can be accomplished by the addition of two more first class engravers. I therefore respectfully recommend that immediate steps be taken to secure the services of two engravers possessed of the necessary qualifications.

At the date of my last report, (October 1, 1859,) First Lieutenant J. R. Smead, 2d artillery, was assigned to the charge of the Engraving Division; he also continued in charge of the Miscellaneous Division for the larger portion of the year.

First Lieutenant N. H. McLean, 2d infantry, joined this office in March last, having succeeded to the vacancy occasioned by the detachment of First Lieutenant J. P. Roy, 2d infantry, from duty on United States Coast Survey; and after acquiring some general knowledge of the office duties, has now been assigned to the charge of the Miscellaneous Division.

The different divisions of the office will now be referred to in general terms.

Computing Division.—This division remains under the charge of Assistant C. A. Schott. He has been assisted in the labors of the division by Assistant T. W. Werner, Messrs. E. Nulty, J. Main, G. Rumpf, J. Wiessner, and W. D. Storke, as regular computers; Mr. J. H. Patton performing the duty of clerk. Assistant A. S. Wadsworth, Mr. B. H. Todd, and R. Freeman have also been temporarily employed in the division.

Tidal Division.—Assistant L. F. Pourtales has continued in charge of this division. His special reports on the progress of the tidal reductions and discussions are made directly to the Superintendent. Messrs. R. S. Avery, John Downes, T. W. Donn, and Charles Balmain have been employed as regular computers in this division; Mr. Pourtales has also occasionally received aid from other employés on the survey during the intervals of their field duties, as is stated in his report, hereto appended.

Drawing Division.—First Lieutenant Thomas Wilson, 5th infantry, has been in charge throughout the year.

It is with great regret that I make known officially to the Superintendent the death, on the 8th of August last, of Assistant W. M. C. Fairfax, late senior draughtsman in this division. His modest deportment and his many private virtues endeared him to all who had the pleasure of his acquaintance. His acquirements in his profession were of the highest order. He had been connected with the Coast Survey since 1843, and the vacancy occasioned by his loss cannot

be easily filled. Lieutenant Wilson alludes to his death, and the loss the Drawing Division has sustained thereby, in appropriate terms. I would refer to his interesting report for more detailed information in relation to the duties of this division.

Engraving Division.—First Lieutenant J. R. Smead, 2d artillery, formerly in charge of the Miscellaneous Division, was, at the date of my last annual report, transferred, as before mentioned, to the more important charge of the Engraving Division.

I have already stated, somewhat in detail, the improvements adopted, and in progress, by means of the successful application of photography in the reductions, and alluded to the necessity of adding to the force of this division.

The Superintendent will perceive, from Lieutenant Smead's detailed report, that this division has made very satisfactory progress under his judicious management.

It is my painful duty to announce to the Superintendent that this division has also met with a serious loss by the death of Mr. J. V. N. Throop, a first-class engraver, who died on the 3d of July last. He had been attached to the Engraving Division for more than six years. He possessed great merit and experience, and particularly excelled as a letter engraver.

Electrotype and Photographic Division.—This division, in which some of the most interesting and useful results to the Survey have been produced, still remains under the charge of Mr. George Mathiot. Mr. Mathiot has been assisted by Mr. D. Hinkle, of whom he speaks, in his report, in the highest terms. Mr. Hinkle has been zealous and active in prosecuting the experiments for the photographic reduction of maps.

These experiments, the result of which I have alluded to in the first part of this report, have involved much labor and study, while, at the same time, the current work of electrotyping has not been neglected.

Fifty-one plates have been electrotyped during the year—nineteen in alto, and thirty-two in basso. One plate has been extended in size, and four plates electrotyped for other departments of the government, and fifty-four plane-table sheets have been reduced by photography. The engraving of these, from the time gained, is nearly finished. It is therefore apparent that the useful results which I confidently anticipated at the date of my last report have already been realized.

Experiments will be continued for bringing, if possible, into successful use the photolithographic process, which I have reason to hope will soon be found advantageous for the more rapid publication of our coarser charts and sketches.

Archives and library.—Eight hundred and four volumes of original and duplicate records, and sixty-three original topographical and hydrographical sheets have been added to the archives of the Survey during the past year. Eighty-four volumes have been purchased for the library, and ninety added by presentation during the same period.

I would respectfully call the attention of the Superintendent to the necessity of providing increased accommodation for the preservation of the archives and valuable engraved plates. Constant additions have so completely filled the limited space available that it is very difficult at this time to preserve the archives in the order that they should be to render them accessible to those who wish to examine the records.

Miscellaneous Division.—To the chief of this division is intrusted the charge of the printing of the maps and charts of the Survey, and also their distribution, and that of the annual report of the Superintendent. First Lieutenant N. H. McLean, 2d infantry, has been recently assigned to this duty.

The number of impressions taken by the printer, and the distribution of the maps, charts, and Coast Survey reports, are shown by Lieutenant J. R. Smead in his report.

Carpentry.—In the carpenters' shop Mr. A. Yeatman remains in charge as master carpenter, assisted by two workmen. The work has been performed in the usual satisfactory manner. There have been made during the year various stands and cases for instruments, engravers' tables, wood-work for self-registering tide-gauges, drawing boards, cases for maps and records,

cylinder cases for magnetic clocks, implements for photographic purposes, packing boxes for instruments, the necessary repairs to instruments and Coast Survey buildings, and, in addition, a large amount of miscellanous work.

Instrument shop.—The force in this shop consists of Mr. J. Vierbuchen, master instrument maker, five workmen, and one apprentice. During the year 27 instruments for geodetic work, 21 for astronomical, 5 for magnetic and telegraphic, 16 for hydrographic, 18 for drawing, 91 for engraving, and 26 topographical instruments have been made, and 84 geodetic, 8 astronomical, 6 magnetic and telegraphic, 39 hydrographic, 25 drawing, 14 engraving, and 46 topographical instruments have been repaired, in addition to a variety of miscellaneous work for the use of the office and parties in the field.

Please find submitted, also, the report of duties performed in the Hydrographic Division, during the past year, under the direction of Commander S. S. Lee, U. S. navy, hydrographic inspector, and furnished to this office.

In conclusion, I would tender my thanks to Com. S. S. Lee and Lieutenant S. Bent, U. S. navy; Professor W. P. Trowbridge, Assistant in the Coast Survey; Samuel Hein, esq., general disbursing agent; and Joseph Saxton, esq., assistant in weights and measures, for the aid they have given to this office on frequent occasions.

First Lieutenant A. P. Hill, 1st artillery, U. S. army, continues as general assistant. His experience, capacity, and knowledge of the duties of this office are well known to the Superintendent.

I beg leave to repeat my statement of last year, that the clerical force of this office is, in my judgment, entitled to an increase of compensation. Their duties, I am confident, are quite as onerous as those of the clerks in other bureaus of the government; yet they receive a much lower compensation.

I have the honor to be, very respectfully, your obedient servant,

W. R. PALMER,

Captain Topographical Engineers, Assist. C. S., in charge of office.

Prof. A. D. BACHE, *Superintendent U. S. Coast Survey.*

Report of Lieut. Silas Bent, U. S. N., on the details of occupation in the Hydrographic Division of the Coast Survey office.

WASHINGTON CITY, *October* 1, 1860.

Since joining this office in March last the general hydrographic duties have been under my supervision, and have consisted chiefly of the examination and verification of original hydrographic sheets, as they have been turned in by the parties afloat, together with the angle and sounding books belonging to those surveys; the examination of the sheets reduced for publication and the plotting upon them of the light-houses, light-vessels, beacons, and buoys, as determined by our own parties in the field, or from data furnished by the Light-house Board; the making or revising of sailing directions and sailing lines; the description of dangers and plotting of mid-channel, tidal, and current stations, and the results of the observations taken at them. Upon these *Mr. Arthur Balbach* has been generally engaged as draughtsman; in addition to which, however, he has been subject to constant calls to supply information required from the office, which his long experience on the survey has made him particularly familiar with; the correction of buoys on published charts and the examination of proofs from newly engraved charts, &c., &c.

Mr. L. Karcher, draughtsman, was transferred to this division in the latter part of April. He has since been employed in making projections for the hydrographic parties; comparative tracings of various localities, of which two or more surveys have been made, so as to exhibit the changes that may have occurred; the plotting of supplementary work furnished from the field; replotting work originally made in advance of the astronomical determinations, &c., &c.

Mr. W. B. McMurtrie, draughtsman, reported for duty temporarily in this division in August,

and has since discharged duties similar to those of Mr. Karcher, except during some ten days, when he was employed in sketching views.

Mr. W. S. Simpson and *Mr. Orton Williams* have recently been appointed aids and assigned to this division to prepare themselves as hydrographic draughtsmen for duty afloat.

Report of Assistant Charles A. Schott, in charge of the Computing Division.

COAST SURVEY OFFICE, *October* 1, 1860.

In conformity with the regulations of the office, I herewith respectfully submit the annual report on the work done by the various computers for the year ending October 1, 1860.

The general organization of the division has not been changed, and it has proved, as in former years, effective and sufficient to meet all requirements. The number of computers remain nearly as before, the present force barely sufficing to keep up all the routine computations. The revision of the astronomical and magnetic work is in a very forward state, and the geodetic computations are as far advanced as the present state of the field-work admits. With an assistant the daily observation of the sun's disk (weather permitting) for number and position of the solar spots has been kept up regularly since the beginning of the year.

During my absence from the office on a magnetic survey in Sections I, II, and III, between August 1 and September 26, Mr. James Main took charge of the division.

Mr. John Wiessner was re-assigned as computer under date of August 20. Mr. William D. Storke having been ordered to field duty, Mr. B. H. Todd was appointed on the 17th of January to supply his place. Mr. J. T. Hoover, who had been clerk to the division for several years, was transferred to your office, and his place was filled by Mr. J. H. Patton, who reported for duty on November 28, 1859.

Assistant A. S. Wadsworth has temporarily assisted in the reduction of magnetic and astronomical observations. He has been thus engaged since the first week of June, and also accompanied me on the magnetic survey in August and September. Sub-Assistant C. Fendall has also been engaged on astronomical work since the middle of July.

The work done by each computer during the year will appear from the following detailed statement:

Assistant Theodore W. Werner reduced Assistant Davidson's triangulation of San Francisco; a part of the Santa Rosa triangulation, Section VII; the triangulation of Damariscotta river and Penobscot bay; of Espiritu Santo bay and vicinity, 1859; of the Gulf of Georgia, W. T., 1859; the triangulation on the Mississippi delta, 1859; of Isle au Breton sound; of Charlotte harbor, and of Santa Cruz island. He also made a preliminary reduction of the Chatham bay triangulation, and reduced the horizontal angles observed at Station Humpback; made part of the reduction of the horizontal angles observed at Howard, Western Ridge, and Chamcook; tabulated Assistant Davidson's horizontal and vertical angles at Sulphur Peak; made an abstract of the angles at Ross mountain, and a new reduction of the azimuth at Station Yard, and completed the reduction of the secondary triangulation south of Cedar Keys.

Mr. Eugene Nulty reduced the azimuth observed at Table Mount, Cal.; the observations for time, latitude, and azimuth made at Port Royal, 1859; the observations for latitude and azimuth at Howard; the observations for time, latitude, and azimuth at Sulphur Peak; the azimuth at East Base, (Edisto;) the observations for latitude and azimuth at Apalachicola, and the azimuth and latitude at Ross mountain, Section X.

Mr. James Main revised the reductions of observations for latitude at Stations Smithville, Howard, Calais, Mount Rose, and Apalachicola; revised the reductions of observations for azimuth at Smithville, Mount Desert, Port Royal, Howard, East Base, Edisto, Savannah Exchange, Humpback, Mount Rose, Apalachicola, Cat island, Lower Mississippi, and East Base,

(Galveston island.) He also made a second reduction of the magnetic observations at Port Royal, Smithville, Western Ridge, Howard, and Chamcook, and reduced the occultations observed at Point Hudson, W. T., for longitude, and has been engaged in various other astronomical computations.

Mr. Gottlieb Rumpf revised the triangulation of Cape Fear; reduced the triangulation near St. Augustine, and the horizontal angles in connection with the Port Royal azimuth; revised the triangulation of Muscongus bay and mouth of the Penobscot; the triangulation of San Antonio and Copano bays, and those of St. Simon's and Sapelo sounds, and the triangulation of the Gulf of Georgia, W. T. He also revised Assistant Farley's triangulation of the mouth of James river, 1859; reduced the additional triangulation of Beaufort river; revised the triangulation of the Mississippi delta; made an adjustment of the triangulation of the James and Appomattox rivers; reduced the Hudson river triangulation; made a preliminary adjustment of the primary triangulation near Epping base; reduced part of the triangulation south of Cedar Keys; made out the horizontal angles of Assistant Boutelle's primary triangulation in Section V, and attended to the insertion of geographical positions in the registers.

Mr. John Wiessner reported for duty August 20, and has been engaged in the completion of the adjustment by least squares of the primary triangulation between Kent Island base and Washington; also in making miscellaneous geodetic computations, and in the reduction of the primary triangulation in Section V.

Mr. William D. Storke, reduced the triangulation from Homosassa river to Raccoon Point, Section VII, and the triangulation of Côte Blanche bay, 1859. He was transferred to a field party December 8, and again reported for duty July 16, 1860, after which he reduced the horizontal angles observed at Howard and Western Ridge, and partially reduced the triangulation south of Cedar Keys. He also attended to clerical duties.

Mr. B. H. Todd reported for duty January 17, and assisted in reducing the triangulation of St. Simon's sound and in the reduction of star places for the latitude of Port Royal. He also made a second reduction of the additional triangulation in Section III; reduced the triangulation of Crescent City, Cal.; assisted in reducing the triangulation of the James and Appomattox rivers, and the additional triangulation in Section II and Section V. He was transferred to a field party August 20, and again reported for duty September 6, and has since been occupied in clerical duties.

Mr. John T. Hoover attended to the clerical duties of the division, and assisted in the preparation of the geographical positions for the Superintendent's report of 1859. He was detached from the division November 23.

Mr. J. Houston Patton reported for duty November 28, and has attended to the clerical duty of the division, besides assisting in special observations. He computed the San Nicolas triangulation of 1858, and prepared illustrative diagrams relating to magnetic discussions.

R. Freeman has supplied the extra copying required for the use of field or office parties.

Mr. Ledyard was engaged in the division during part of the month of July.

Since January 1, 118 reports have been submitted on various subjects connected with the division. Notice of my labors in relation to solar spot observations, terrestrial magnetism, and the solar eclipse of July, will appear in another part of the Superintendent's report.

Report of Assistant L. F. Pourtales, in charge of the Tidal Division.

COAST SURVEY OFFICE, *October* 1, 1860.

The following report on the occupation of the computers in this division during the past year is respectfully submitted:

Mr. R. S. Avery made a revision of the tidal reductions of the series observed at Old Point

Comfort; he also reduced the tidal observations of Tahiti, Cape San Lucas, and the decomposed tides of the several stations occupied simultaneously on the coast of Florida. During my absence from the office in part of the months of April and June, and from June 9 to September 15, Mr. Avery had charge of this division.

Mr. John Downes was employed in reading off the hourly heights of the tides from the self-registering observations of the coast of Florida. He has also plotted the meteorological observations taken at all the stations on the Atlantic coast for transmission to the meteorological department of the British Board of Trade.

Mr. J. W. Donn has read off and tabulated the self-registering observations; has kept the register of the observations received, and corresponded with the observers. He has also had charge of the self-registering tide-gauge at the Washington navy yard, and has made ordinary reductions, and done miscellaneous work.

Mr. Chas. Balmain reported for duty January 7, and has been engaged in decomposing the tidal curves of the Florida stations into their component diurnal and semi-diurnal waves.

Mr. J. Gilliss was engaged during the month of December, and until January 19, in miscellaneous work, but chiefly in working out the daily inequalities of some of the stations in San Francisco bay. He then left the office for field-duty on the Western Coast.

Mr. J. R. Gilliss reported for duty April 16, and has been employed since in plotting and decomposing tidal curves from the Florida and Gulf stations.

Mr. L. M. Johnson was employed in ordinary reductions from February 24 until April 18, when he joined the party of Assistant H. Mitchell.

Mr. B. H. Todd was employed in ordinary reductions from January 3 to 16, when he was transferred to the computing division.

Sub-Assistant C. Fendall made graphical decompositions of tides in October and part of November, 1859, during the interval between his returning from field-duty in the north and proceeding to the south.

M. Thomas and *S. D. Pendleton* have made ordinary reductions of tides for most of the permanent stations.

Report of Lieut. Thomas Wilson, U. S. A., Assistant in charge of the Drawing Division.

COAST SURVEY OFFICE, *October* 1, 1860.

I have the honor to submit the following report of the operations of the Drawing Division since November 1, 1859:

The division has remained under my charge since the date of my last report; for a full statement of the work accomplished during the year I respectfully refer to the lists presented below, where are mentioned in detail the duties performed by each draughtsman, and the maps and sketches completed or in progress.

The division has experienced a severe loss during the year in the demise of Assistant W. M. C. Fairfax, draughtsman, who died on the 8th of August. He ranked at the head of his profession, and for seventeen years (since 1843) had devoted himself to his duties with unremitting fidelity and remarkable success; his exquisite reductions on the $\frac{1}{80000}$ and $\frac{1}{400000}$ scales are monuments of his extraordinary skill, and they can never be excelled; this loss will always be felt, and his place will be difficult to fill.

The number of draughtsmen proper is three less than at the close of last year; two tracers for *photography* have been added to the force. Until the beginning of the year the subject of projects had been an exclusive branch in the division, and the entire time and attention of a first class draughtsman had been given to it. I have since given my best personal attention to

the study. Forty-one projects on the full scale for charts of various scales, from $\frac{1}{400000}$ to $\frac{1}{20000}$, and of sketches, have been drawn, submitted, and approved during the year. In the previous year nineteen projects on the full scale had been submitted and approved. The success of reduction by photography for the $\frac{1}{80000}$ scale and analogous charts is no longer a matter of question; the results speak for themselves, and in the future this method alone will be followed, except in cases to be mentioned presently. The mode of proceeding is as follows:

The triangulation points of the sheet to be reduced are first examined to determine if they agree with the standard geographical position of the same points furnished by the Computing Division; first, as regards their own relative position, and then in reference to the projection found on the sheet; if any irregularity is found, it is corrected by the most approved means.

The features, both natural and artificial, of the sheet, are then generalized according to rules adopted for the use of the Coast Survey office, a careful study of the sheet being made with regard to the peculiarities of the locality, and the demand specially made of features to be preserved for topographical record, and for use in navigation, features which, in some localities, are insignificant, being of primary importance in others. A projection of the limits of the sheet is made on tracing vellum, and the generalized features traced thereupon, lines, &c., being made of such size and thickness as will conform (when reduced to the $\frac{1}{80000}$ scale) to the rules given for the published maps on that scale. The tracing is made step by step, adjustments being made for shrinkage or other irregularity.

A photograph of the tracing is then made on glass, and sent to the Drawing Division for verification; this is returned for use in the Engraving Division, the outline being traced from it, and entered in the copper.

A photograph on paper of the same scale is taken to be colored, according to the established rules for representing topography, (where masses are of such a size as to warrant it,) and to be finished by a competent draughtsman, with the incidental features that are too small to be represented in such a manner.

Where the character of the locality is one of complex contour the photographic print is made on the $\frac{1}{40000}$ scale, hachured in the Drawing Division, and then reduced by photography to the $\frac{1}{80000}$ scale for the use of the engraver.

The prints of the different sheets are put down in their proper places on the projected limits of the map to be published, and having been colored and finished by pen-work in detail are ready for the engraver.

I take great pleasure in here commending the very valuable services of Mr. E. Hergesheimer, draughtsman, whose time has been almost exclusively devoted to this branch of the service; his thorough knowledge of the subject, and his energy and zeal are perceptible in the progress which has been made.

Hand reduction is still employed for charts far advanced in engraving. Even in such cases, however, a great saving of time and labor has been gained in the use of colors, the prominent idea being to replace by them well-defined masses of woods, sand, marsh, &c., &c., instead of indicating them by the old style of elaborate pen delineation.

The great assistance given by photography renders unnecessary the employment of other draughtsmen to fill the places of those who have left during the year.

Assistant W. M. C. Fairfax was employed upon the reduction of topography of coast maps and charts; No. 8, from Seguin Island light to Kennebunkport, Me., scale $\frac{1}{80000}$; No. 9, from Cape Neddick, Me., to Cape Ann, Mass., $\frac{1}{80000}$; Nos. 35 and 36, Chesapeake bay, from Pocomoke sound to entrance, Md. and Va., $\frac{1}{80000}$; No. 37, from Cape Henry, Va., to Currituck sound, N. C., $\frac{1}{80000}$; No. 41, Albemarle sound, (eastern sheet,) $\frac{1}{80000}$; and No. 93, from Lake Borgne to Lake Pontchartrain, La.; also upon the reduction of the topography of general coast chart No. VI, from Ocracoke inlet, N. C., to Charleston, S. C., scale $\frac{1}{400000}$; and No. VII, from

Winyah bay, S. C., to St. John's river, Fla., scale $\frac{1}{400000}$. The office lost his valuable services by his death, which occurred on the 8th of August.

Assistant M. J. McClery has been employed upon the reduction of the topography of coast map and chart No. 21, New York bay and harbor, $\frac{1}{80000}$; he has also filled in the topography of that chart upon an outline drawn by photography, scale $\frac{1}{80000}$; and has also hachured part of the chart on a $\frac{1}{40000}$ scale, which by photography has been reduced to the $\frac{1}{80000}$. He has been engaged upon the reduction of a photographed outline of coast map and chart No. 9, from Cape Neddick, Me., to Cape Ann, Mass., $\frac{1}{80000}$; and has completed the reduction of the topography of coast map and chart No. 31, (additions,) Chesapeake bay, from head of the bay to the mouth of Magothy river, Md., $\frac{1}{80000}$. He has been also engaged upon the reduction of the topography of coast maps and charts Nos. 84 and 85, from Ocilla river to Cape St. Blas, Fla., scale $\frac{1}{80000}$; on general coast chart No. IV, from Cape May, N. J., to Currituck sound, N. C., scale $\frac{1}{400000}$, and No. VI, from Ocracoke inlet, N. C., to Charleston, S. C; on the topography of the chart of Hempstead harbor, L. I., $\frac{1}{20000}$; and on that of the commissioner's map of New York harbor scale $\frac{1}{20000}$. He has also been engaged upon the reduction of the topography of general coast chart No. XIV, from Choctawhatchee bay to Pensacola bay $\frac{1}{400000}$.

Mr. E. Hergesheimer, until the 5th of December, was engaged in reducing topography for a chart of the Sheepscot and Kennebec rivers, Me., scale $\frac{1}{40000}$, and on verifications and projections. From that time until the 1st of July he assisted Mr. Whiting in the preparation of the new instructions for the Drawing and Engraving Divisions. Since the 1st of July he has been occupied in the generalization of sheets for photography, and in that department of the work has been engaged upon the following coast maps and charts, scale $\frac{1}{80000}$, viz: No. 8, Seguin island, to Kennebunkport, Me.; No. 9, from Cape Neddick, Me., to Cape Ann, Mass.; No. 11, from Plymouth harbor to Hyannis harbor, Mass.; No. 21, New York bay and harbor; No. 46, from Cape Lookout to Bogue inlet, N. C.; No. 47, from Bogue inlet to Barren inlet, N. C.; No. 48, from Barren inlet to Lockwood's Folly inlet, N. C.; No. 54, from Fripp's inlet, S. C., to Ossabaw sound, Ga.; No. 60, from St. Augustine to Tomoka creek, Fla.; No. 81, from Chassahowitzka river to Cedar keys, Fla.; No. 108, Matagorda and Lavaca bays, Texas; and on San Francisco bay. He has also made experiments in reducing by photography the hydrography of preliminary sea-coast chart No. 11, $\frac{1}{200000}$, from Cape Hatteras to Cape Lookout, N. C., and has likewise verified the photographed negatives before they were engraved. He has now in hand the chart of the Sheepscot and Kennebec rivers.

Mr. A. Lindenkohl has completed the reduction of the hydrography of coast map and chart No. 14, from Buzzard's bay to Block Island sound, R. I., $\frac{1}{80000}$, (additions,) and has continued that of the topography of coast maps and charts No. 36, Chesapeake bay, from York river to Cape Henry, Va., $\frac{1}{80000}$; No. 68, Florida reefs and keys, from Key Biscayne to Carysfort reef, $\frac{1}{80000}$; No. 100, from Point-au-fer to Marsh island, La., $\frac{1}{80000}$; and of the topography and hydrography of coast map and chart entitled Washington sound, &c., $\frac{1}{80000}$; also upon the reduction of the topography of general coast chart No. VII, from Winyah bay, S. C., to St. John's river, Fla., $\frac{1}{400000}$; that of the topography and hydrography of No. X, Florida reefs and keys, from Cape Florida to Cape Sable, $\frac{1}{400000}$; No. XIII, from Waccasassa bay to Choctawhatchee bay, Fla., $\frac{1}{400000}$; and No. XVI, from Galveston bay to the Rio Grande, Texas, $\frac{1}{400000}$. He has made additions to Alden's reconnaissance of the western coast, $\frac{1}{1200000}$, and has been engaged upon progress sketches, projections for field parties, projects, projections on copper, verifications, and miscellaneous duties in the division.

Mr. W. P. Schultz reduced the hydrography of the Patuxent river, (lower sheet,) $\frac{1}{60000}$, and was engaged upon projects, progress sketches, Gulf Stream diagrams, and sketches, until the 4th of February, when he was discharged.

Mr. L. D. Williams has made additions to preliminary sea-coast chart No. 3, from Cape

Smallpoint, Me., to Cape Cod, Mass.; Nos. 11 and 12, from Cape Hatteras to Cape Fear, N. C., $\frac{1}{200000}$; has continued the reduction of the hydrography of general coast chart No. VI, from Ocracoke inlet, N. C., to Charleston, S. C., $\frac{1}{400000}$; and that of the topography and hydrography of the Hudson river chart, $\frac{1}{60000}$. He has also reduced the topography and hydrography of St. Mary's river, Md., $\frac{1}{60000}$; made additions to the Congress map, diagrams of the Gulf Stream, explorations, and projections on copper, and has been employed upon verifications.

Mr. A. Strausz was employed upon the reduction of preliminary sea-coast chart No. 2, from Isle au Haut to Cape Elizabeth, Me., $\frac{1}{200000}$; also upon the reduction of the hydrography of preliminary sea-coast chart No. 25, from Santa Rosa sound to Mobile bay, Ala., $\frac{1}{200000}$; and of the hydrography of coast maps and charts No. 9, from Cape Neddick, Me., to Cape Ann, Mass., $\frac{1}{80000}$; Nos. 28, 29, and 30, from Cape May, N. J., to Great Machipongo inlet, Va., $\frac{1}{80000}$; No. 37, from Cape Henry, Va., to Currituck sound, N. C., $\frac{1}{80000}$; No. 48, from Barren inlet to Lockwood's Folly inlet, N. C., $\frac{1}{80000}$; No. 58, from St. Mary's river to St. John's river, Fla., $\frac{1}{80000}$; No. 70, from Long key to Bay Pine key, Fla., $\frac{1}{80000}$; No. 85, from east end of St. George's sound to Cape St. Blas, Fla., $\frac{1}{80000}$; and No. 108, Matagorda and Lavacca bays, Texas, $\frac{1}{80000}$. He made additions to the chart of Portland harbor, Me., $\frac{1}{20000}$; reduced the hydrography of Hempstead harbor, Long Island, $\frac{1}{20000}$; and that of Port Royal, &c., S. C., $\frac{1}{60000}$. He made additions to the reduction of the hydrography of the east entrance to St. George's sound, Fla., $\frac{1}{40000}$; executed a new edition of the chart of Washington sound, &c., $\frac{1}{200000}$; and has been employed upon projections on copper and projections for field parties.

Mr. W. T. Martin has filled in topography upon a photographed portion of the outline of coast map No. 48, $\frac{1}{80000}$, from Barren inlet to Lockwood's Folly inlet, N. C., $\frac{1}{80000}$; completed the topography of No. 47, from Bogue inlet to Barren inlet, N. C., $\frac{1}{80000}$, (upon a photographed outline;) and has been engaged upon that of No. 81, from Chassahowitzka river to Cedar keys, Fla. He completed the reduction of the topography of coast map and chart No. 92, from Round island to Grand island, La., $\frac{1}{80000}$, (additions;) and has been engaged upon that of No. 93, from Lake Borgne to Lake Pontchartrain, La., $\frac{1}{80000}$; and No. 108, Matagorda and Lavacca bays, Texas, $\frac{1}{80000}$. He commenced the reduction of the hydrography of James River entrance, Va., $\frac{1}{80000}$; reduced the hydrography of the "Rigolets," La., $\frac{1}{20000}$; has also been engaged on verification.

Mr. J. J. Ricketts entered the office on the 5th of January, and left it for field duty on the 15th of April. He was occupied while in the office upon the reduction of the hydrography of general coast chart No. IV, from Cape May, N. J., to Currituck sound, N. C., $\frac{1}{400000}$, and preliminary sea-coast chart No. 14, from Cape Roman, S. C., to Savannah, Ga., $\frac{1}{200000}$. He also reduced the hydrography of Bull's bay, S. C., $\frac{1}{60000}$.

Mr. W. B. McMurtrie was, on the 2d of January, temporarily assigned to duty in the office, awaiting instruction for the field, which he received on the 1st of March. While in the office he reduced the hydrography of Sapelo sound, Ga., $\frac{1}{30000}$, and was engaged in lettering and inking topographical sheets, and miscellaneous duties.

Mr. L. Karcher was assigned to duty in the office on the 21st of December, 1859; worked on the reduction of the hydrography of preliminary sea-coast chart No. 25, from Santa Rosa sound to Mobile bay, Ala., $\frac{1}{200000}$, and that of coast maps and charts Nos. 33, 34, and 35, Chesapeake bay, from Hudson river, Md., to York river, Va., scale $\frac{1}{80000}$. He made additions to the hydrography of the east entrance to St. George's sound, $\frac{1}{40000}$, and completed that of Apalachicola bay, $\frac{1}{40000}$. Besides making a comparative chart of Pensacola harbor, Fla., $\frac{1}{30000}$, and projections for field parties, and replotting certain hydrographic sheets, he was engaged upon progress sketches and lettering. Mr. Karcher was transferred to the Hydrographic Division on the 19th of April.

Mr. S. B. Linton has been engaged upon the reduction of the topography of coast map and chart No. 74, from Lower Matacumbe key to Cape Sable, Fla., $\frac{1}{80000}$; and of Portland harbor, $\frac{1}{20000}$. He has reduced hydrography for the chart of Patuxent river, Md., (upper sheet,) $\frac{1}{30000}$, and has been employed on the topography of the lower sheet, $\frac{1}{60000}$. He has reduced the topography and hydrography of St. Simon's sound, Brunswick harbor, and Turtle river, Ga., $\frac{1}{40000}$, and has made additions to the reduction of the topography of Pensacola bay, $\frac{1}{30000}$; has reduced the hydrography of St. Augustine harbor, Fla., $\frac{1}{30000}$; that of San Pedro harbor, Cal., $\frac{1}{30000}$; and the topography and hydrography of Crescent City harbor, Cal., $\frac{1}{20000}$. He has also been employed upon progress sketches, diagrams of magnetic results, tracings, projections for field parties, and in lettering reductions.

Mr. F. Fairfax entered the office on the 6th February, and has been engaged on the topographical reduction of Portland harbor, $\frac{1}{20000}$. He has reduced the topography and hydrography for a map of North river, Va., $\frac{1}{40000}$, and the topography of St. Augustine harbor, Fla., $\frac{1}{30000}$; has redrawn the triangulation sketch of Hudson river, N. Y., $\frac{1}{200000}$, and $\frac{1}{100000}$; and has been employed upon projections for field parties, progress sketches, statistics, in lettering reductions, coloring maps, and in tracing.

Mr. J. W. Maedel entered the office on the 1st of November, 1859, and was employed on tracings until the 19th of January. Since then he has been engaged in making tracings of original sheets for the photograph.

Mr. B. Hooe, jr., has continued on tracings.

Mr. W. H. Gardner entered the office on the 1st of December, and has been engaged in tracing original topographical sheets for photography.

Mr. A. J. De Zeyk was employed in the office from the 17th of May until the 5th of September, and has been employed upon tracings and statistics.

Mr. W. Fairfax entered the office on the 10th of September, and has been engaged in tracing.

Mr. H. Lindenkohl, on contract, reduced the hydrography of coast map and chart No. 8, from Seguin island to Kennebunkport, Me., $\frac{1}{80000}$, and the remaining topography and the hydrography of No. 100, from Point-au-fer to Marsh island, La., $\frac{1}{80000}$.

Mr. W. Grupe, on contract, has reduced the remaining hydrography of general coast chart No. IV, from Cape May, N. J., to Currituck sound, N. C., $\frac{1}{400000}$.

List of maps and sketches completed or in progress during the year ending November 1, 1860, arranged in order of sections.

Name.	Scale.	Description.	Remarks.
SECTION I.—*Coast of Maine, New Hampshire, Massachusetts, and Rhode Island.*			
Progress sketch A	1-600,000		Completed.
Progress sketch A *bis*	1-400,000		Do.
Preliminary sea-coast chart, No. 2, from Isle-au-haut to Cape Elizabeth, Maine	1-200,000	Preliminary chart	In progress.
Sheepscot and Kennebec rivers, Maine	1-40,000	Finished map	Do.
Portland harbor, Maine	1-20,000	do	Completed.
Preliminary sea-coast chart, No. 3, from Cape Small Point, Maine, to Cape Cod, Massachusetts	1-200,000	Preliminary chart	In progress.
Coast map and chart, No. 8, from Seguin island light to Kennebunkport, Maine	1-80,000	Finished map and chart	Do.
Coast map and chart, No. 9, from Cape Neddick, Maine, to Cape Ann, Massachusetts	1-80,000	do	Do.
Coast map and chart, No. 11, from Plymouth harbor to Hyannis harbor, Massachusetts	1-80,000	do	In progress; outline by photography.
Coast map and chart, No. 14, from entrance to Buzzard's bay to entrance to Block island sound, Rhode Island, (additions)	1-80,000	do	Completed.
SECTION II.—*Coast of Connecticut, New York, New Jersey, and Delaware, north of Cape Henlopen.*			
Progress sketch B	1-400,000		Do.
Triangulation sketch, Hudson river	1-200,000		Do.
Triangulation sketch, Hudson river	1-100,000		Do.
Hempstead harbor, Long Island	1 20,000		Do.
Coast map and chart, No. 21, New York bay and habor	1-80,000	Finished map and chart	In progress; outline by photography.
Commissioner's map, New York bay and harbor	1-20,000	Finished map	In progress.
Hudson river, from entrance to Sing Sing, New York	1-60,000	do	Do.
SECTION III.—*Coast of Delaware, south of Cape Henlopen, Maryland and Virginia, north of Cape Henry.*			
Progress sketch C	1-400,000		Completed.
General coast chart, No. IV, from Cape May, New Jersey, to Currituck sound, North Carolina	1-400,000	Finished chart	In progress.
Coast map and chart, No. 28, from Cape May, New Jersey, to Isle of Wight, Delaware	1-80,000	Finished map and chart	Completed.
Coast map and chart, No. 29, from Isle of Wight, Delaware, to Chincoteague inlet, Virginia	1-80,000	do	In progress; outline partly by photography.
Coast map and chart, No. 30, from Chincoteague inlet, Virginia, to Great Machipongo inlet, Va	1-80,000	do	In progress; outline by photography.
Coast map and chart, No 31, Chesapeake bay, from head of the bay to mouth of the Magothy river, Maryland, (additions)	1-80,000	do	Completed.
Coast map and chart, No. 33, Chesapeake bay, from Hudson river to Potomac river, Maryland	1-80,000	do	In progress.
Patuxent river, Maryland, (upper sheet)	1-30,000	Preliminary chart	Do.
Patuxent river, Maryland, (lower sheet)	1-60,000	Finished map	Do.
St. Mary's river, Maryland	1-60,000	do	Completed.
Coast map and chart, No. 34, Chesapeake bay from Potomac river, Maryland, to entrance to Pocomoke sound, Virginia	1-80,000	Finished map and chart	In progress.
Coast map and chart, No. 35, Chesapeake bay, from Pocomoke sound to York river, Virginia	1-80,000	do	Do.
Coast map and chart, No. 36, Chesapeake bay, from York river to entrance, Virginia	1-80,000	do	Do.
James river entrance, Virginia	1-80,000	Finished map	Do.
SECTION IV.—*Coast of Virginia, south of Cape Henry, and North Carolina, north of Cape Fear.*			
Progress sketch D	1-600,000		Completed.
Coast map and chart, No. 37, from Cape Henry, Virginia, to Currituck sound, North Carolina	1-80,000	Finished map and chart	In progress.
North river, Virginia	1-40,000	Finished map	Completed.

List of maps and sketches, &c.—Continued.

Name.	Scale.	Description.	Remarks.
SECTION IV—Continued.			
Coast map and chart, No. 41, Albemarle sound, (eastern sheet)	1-80,000	Finished map and chart	In progress.
Preliminary sea-coast chart, No. 11, from Cape Hatteras to Cape Lookout, North Carolina	1-200,000	Preliminary chart	Do.
Preliminary sea-coast chart, No. 12, from Cape Lookout to Cape Fear, North Carolina	1-200,000	......do	Do.
Coast map and chart, No. 46, from Cape Lookout to Bogue inlet, North Carolina	1-80,000	Finished map and chart	In progress; outline by photography.
Coast map and chart, No. 47, from Bogue inlet to Barren inlet, North Carolina	1-80,000	......do	Do.
Coast map and chart, No. 48, from Barren inlet to Lockwood's Folly inlet, North Carolina	1-80,000	......do	Do.
Diagrams of Gulf Stream temperature		Diagrams	Completed.
SECTION V.—*Coast of North Carolina, south of Cape Fear, South Carolina, and Georgia.*			
Progress sketch E	1-600,000		Do.
General coast chart, No. VI, from Ocracoke inlet, North Carolina, to Charleston, South Carolina	1-400,000	Finished chart	In progress.
General coast chart, No. VII, from Winyah bay, South Carolina, to St. John's river, Florida	1-400,000	......do	Do.
Preliminary sea-coast chart, No. 14, from Cape Roman, South Carolina, to Savannah, Georgia	1-200,000	Preliminary chart	Do.
Bull's bay, South Carolina	1-60,000	......do	Completed.
Coast map and chart, No. 53, from Rattlesnake shoals to St. Helena sound, South Carolina	1-80,000	Finished map and chart	In progress.
Port Royal entrance, and Beaufort river, South Carolina	1-60,000	Preliminary chart	Completed.
Coast map and chart, No. 54, from Fripp's inlet, South Carolina, to Ossabaw sound, Georgia	1-80,000	Finished map and chart	In progress; outline by photography.
Sapelo sound, Georgia	1-30,000	Finished map	Completed.
St. Simon's sound, Brunswick harbor, and Turtle river, Georgia	1-40,000	......do	Do.
SECTION VI.—*Coast of Florida, from St. Mary's river to St. Joseph's bay.*			
Progress sketch F, (showing a general reconnaissance)	1-1,200,000		Do.
Progress sketch F, (reefs and keys)	1-400,000		Do.
Coast map and chart, No. 58, from St. Mary's river to St. John's river, Florida	1-80,000	Finished map and chart	In progress; outline by photography.
St. Augustine harbor, Florida	1-30,000	Preliminary chart	Completed.
Coast map and chart, No. 60, from St. Augustine harbor to Tomoka creek, Florida	1-80,000	Finished map and chart	In progress; outline by photography.
Coast map and chart, No. 68, from Key Biscayne to Craysfort reef, Florida	1-80,000	......do	Completed.
General coast chart, No. X, from Cape Florida to Cape Sable, Florida	1-400,000	Finished chart	In progress.
Coast map and chart, No. 70, from Long key to Bay Pine key, Florida	1-80,000	Finished map and chart	Do.
Coast map and chart, No. 74, from Lower Matacumbe key to Cape Sable, Florida	1-80,000	......do	Do.
SECTION VII.—*Coast of Florida, west of St. Joseph's bay, and Alabama, east of Mobile bay.*			
Progress sketch G	1-600,000		Completed.
General coast chart, No. XIII, from Waccasassa bay to Choctawhatchee bay, Florida	1-400,000	Finished map and chart	In progress.
Coast map and chart, No. 81, from Chassahowitzka river to Cedar keys, Florida	1-80,000	......do	In progress; outline by photography.
Coast map and chart, No. 84, from Ocilla river, Florida, to Crooked river, Florida	1-80,000	......do	In progress.
Coast map and chart, No. 85, from east end of St. George's island to Cape St. Blas, Florida	1-80,000	......do	Do.
St. George's sound, entrance, (additions)	1-40,000	Finished map	Completed.

List of maps and sketches, &c.—Continued.

Name.	Scale.	Description.	Remarks.
SECTION VII—Continued.			
Apalachicola bay, Florida	1-40,000	Finished map	Completed.
Preliminary sea-coast chart, No. 25, from Santa Rosa sound to Mobile bay, Alabama	1-200,000	Preliminary chart	In progress.
Pensacola harbor, Florida, (additions)	1-30,000	Finished map	Completed.
Pensacola harbor, Florida	1-30,000	Comparative chart	Do.
Escambia and Santa Maria de Galvez bays, Alabama	1-30,000	Preliminary chart	In progress.
Deep-sea soundings, Gulf of Mexico	1-1,240,000	Sketch	Completed.
SECTION VIII.—*Coast of Alabama, west of Mobile bay, Mississippi and Louisiana, east of Vermilion bay.*			
Progress sketch H	1-600,000		Do.
General coast chart, No. XIV, from Choctawhatchee bay, Florida, to Mississippi delta, Louisiana	1-400,000	Finished chart	In progress.
The Rigolets, Louisiana	1-20,000	Finished map	Completed.
Coast map and chart, No. 92, from Round island to Grand island, Louisiana, (additions)	1-80,000	Finished map and chart	Do.
Coast map and chart, No. 93, from Lake Borgne to Lake Pontchartrain, Louisiana	1-80,000	do	In progress.
Coast map and chart, No. 100, from Point-au-fer to Marsh island, Louisiana	1-80,000	do	Do.
SECTION IX.—*Coast of Louisiana, west of Vermilion bay, and of Texas.*			
Progress sketch I	1-600,000		Completed.
General coast chart, No. XVI, from Galveston bay to the Rio Grande, Texas	1-400,000	Finished chart	In progress.
Coast map and chart, No. 108, Matagorda and Lavacca bays, Texas	1-80,000	Finished map and chart	In progress; outline by photography.
Coast map and chart, No. 109, from Matagorda bay to Aransas bay, Texas	1-80,000	do	Do.
SECTION X.—*Coast of California.*			
Progress sketch J, (from San Diego to Point Sal)	1-600,000		Completed.
Progress sketch J, No. 2, (from Point Sal to Tomales bay)	1-600,000		Do.
Alden's reconnaissance of the western coast, (additions)	1-1,200,000	Sketch	Do.
San Pedro harbor, California	1-30,000	Preliminary chart	Do.
San Francisco bay and harbor, California	1-80,000	Finished map	Completed; outline by photography.
Crescent city harbor	1-20,000	do	Completed.
SECTION XI.—*Coast of Oregon and Washington Territory.*			
Progress sketch K	1-600,000		Completed.
Washington sound and approaches, (new edition)	1-200,000	Preliminary chart	Do.
Coast map and chart "E," Washington sound, &c.	1-80,000	Finished map and chart	In progress.
Diagrams illustrating discussions of magnetical observations		Diagrams	Completed.
Mitchell's improved apparatus for measuring currents, and improved form of piles for securing sea structures			Drawn in Publication Division.

Report of Lieut. J. R. Smead, U. S. A., in charge of the Engraving Division.

ENGRAVING DIVISION,
U. S. Coast Survey Office, October 1, 1860.

I have the honor to present the annual report of the operations of this division, which has been under my charge since the date of the last report.

Mr. Edward Wharton has been continued as assistant in the division, and I take pleasure in acknowledging that I am indebted to him for his courtesy, industry, and experience. His worth and efficiency are so well known in the office that I need not remark further in this connection.

Mr. C. C. Callan replaced Mr. William M. Maynadier as clerk July 1, the latter having been transferred to the Miscellaneous Division. Mr. Callan gives me much satisfaction in the performance of his duties.

The force at present consists of twenty-four engravers of various degrees of skill, from the beginner to the finished workman. A list is given below, with the class of each (as topographical, letter, or miscellaneous engraver) mentioned, and the work accomplished by each during the year.

This force, small as it was, when the amount of work accumulating from both hand and photographic reduction is considered, has been still further reduced by the death of Mr. J. V. N. Throop on the third of last July. Mr. Throop was an old and skilful letter engraver, and had served six years in this division. I trust the vacancy may soon be filled.

The same need of first class experienced workmen exists now as formerly, and to a greater extent; for, as the whole work expands, the demand upon the Engraving Division increases, and that for work of greater excellence, as the preliminary and sketch work of former years, is now being replaced by finished maps and charts, which latter, in addition to accuracy, are expected to exhibit the highest style of the art.

The amount of useful information placed upon our charts and sketches, in the form of notes, sailing directions, description of dangers, light-house, tidal, and other tables, has increased from year to year, and still continues to increase, making it very difficult to provide for this branch of the engraving with the present force of letter engravers.

An increase of one first class letter engraver, and the permission to give out on contract some first class topography, would enable this division to complete in the next year an amount of work greater in proportion to the expenditures than in any preceding year, and for the simple reason that the engraving force would be better *balanced* as to its different classes, and work could be laid out to greater advantage.

The means to carry out the suggestion contained in the above statement are available, and can be secured immediately upon the receipt of the proper authority.

The engraving of the finished charts of Rockport harbor and Lynn harbor, Mass., Hempstead harbor, L. I., York river, Va., (upper sheet,) Albemarle sound, N. C., $\frac{1}{80000}$, (eastern sheet;) Albemarle sound, N. C., $\frac{1}{80000}$, (western sheet;) coast chart No. 91, $\frac{1}{80000}$, (Mississippi sound;) San Francisco bay, Cal., $\frac{1}{50000}$; and new editions of Muskeget channel, Mass., and Captain's island east and west, Long Island sound, have been completed.

The following second class charts and sketches have been completed: preliminary sea-coast chart No. 4, $\frac{1}{200000}$; preliminary charts of Patuxent river, Md., Sapelo sound, Ga., Bull's bay, S. C., and San Pedro harbor, Cal.; also eastern part of St. George's sound, Fla., Rigolets, La., and Crescent City harbor, Cal.

Plates of the following first class charts have been prepared for preliminary editions: Coast chart No. 8, (Casco bay, &c.,) $\frac{1}{80000}$; coast charts Nos. 34, 35, and 36, (the lower Chesapeake series,) $\frac{1}{80000}$; Portland harbor, Maine, St. Mary's river, Md., Port Royal entrance,

S. C., coast chart No. 71, (Florida reefs and keys,) $\frac{1}{80000}$; and coast chart No. 108, (Matagorda bay,) $\frac{1}{80000}$.

The following first class finished maps and charts of the $\frac{1}{80000}$ series, viz: Nos. 9, 11, 12, 13, 14, 21, 29, 31, 32, 33, 68, 92, 106, and 107, embracing most of the important points of the Atlantic and Gulf coast, have been pressed forward as rapidly as the engraving force would allow, as also the following important harbor and other charts, viz: Sea coast, Nos. 3, 11, and 14, $\frac{1}{1200000}$ series, Hudson river, N. Y., Rappahannock river, Va., and San Pablo bay, Cal.

Mr. McCoy, topographical engraver, has engraved a portion of the topography of coast map and chart No. 29, $\frac{1}{80000}$, directly from the plane table sheet, the outlines having been first engraved from a photographic reduction, thus demonstrating the practicability of this most economical method, at least in the case of engravers who, like Mr. McCoy, possess superior skill. He has completed specimens of topographical signs, &c., to be used as standards in the division; also the topography of Hempstead harbor, Long Island sound, and is now engraving coast chart and map No. 11, Plymouth harbor to Hyannis harbor, Mass., $\frac{1}{80000}$; upon which he has made considerable progress.

Mr. Knight, letter engraver, has engraved the title and notes on coast chart No. 36, $\frac{1}{80000}$; title and soundings on coast chart No. 35 $\frac{1}{80000}$; notes and lettering on coast chart No. 34, $\frac{1}{80000}$; and on chart of San Francisco bay $\frac{1}{50000}$; also miscellaneous work on coast charts Nos. 13, 15, 17, 19, 108, and other charts.

Mr. Rolle, topographical engraver, has completed the topography of coast chart No. 31, $\frac{1}{80000}$; additions to the topography of Alden's reconnaissance of the Western Coast; and has made progress on coast chart No. 9, $\frac{1}{80000}$.

Mr. Enthoffer, topographical engraver, has been employed during the whole year upon the topography of coast chart No. 32, $\frac{1}{80000}$.

Mr. Sengteller, topographical engraver, has completed the topography of coast chart No. 12, $\frac{1}{80000}$; and has nearly completed the sanding of coast chart No. 68, $\frac{1}{80000}$.

Mr. Phillips, topographical engraver, has been employed principally upon the outlines and topography of coast chart No. 34, $\frac{1}{80000}$; but has also executed additions to topography on coast chart No. 92, $\frac{1}{80000}$; retouched the topography of Muskeget channel and mouth of Chester river, and commenced the sanding on coast chart No. 31, $\frac{1}{80000}$.

Mr. Metzeroth, topographical engraver, has completed the sand on coast chart No. 13, $\frac{1}{80000}$; engraved outlines of Portland harbor and additional topography on the Pensacola harbor chart, besides some miscellaneous work, and has made considerable progress on the sanding of coast chart, No. 31, $\frac{1}{80000}$.

Mr. Blondeau, topographical engraver, has completed the topography of San Pablo bay, California, $\frac{1}{50000}$; and has commenced topography on general coast chart No. II, $\frac{1}{400000}$.

Mr. Evans, topographical engraver, has been employed principally on the Hudson river chart, $\frac{1}{60000}$, besides some miscellaneous work.

Mr. Barnard, topographical engraver, has engraved outlines of Hempstead harbor and St. Mary's river; has retouched topography and sand on Nantucket harbor; sea-coast chart No. 4, $\frac{1}{200000}$; Salem harbor $\frac{1}{25000}$; York river, Va., $\frac{1}{60000}$; and completed sanding of coast chart No. 92, $\frac{1}{80000}$; and has nearly completed the sanding of Chesapeake bay, No. 3, $\frac{1}{80000}$.

Mr. A. Maedel, topographical engraver, has completed the topography of coast chart No. 40, $\frac{1}{80000}$, and some miscellaneous work, and is now engraving topography on the chart of Rappahannock river, Va., (lower sheet,) $\frac{1}{60000}$.

Mr. Kondrup, miscellaneous engraver, has completed soundings, &c., on Chesapeake, No. 6, $\frac{1}{80000}$; some miscellaneous work; and is now far advanced on first class outlines of coast chart No. 21, $\frac{1}{80000}$, from photographic reductions.

Mr. E. A. Maedel, letter engraver, has engraved title lettering and soundings on coast chart No. 71, $\frac{1}{80000}$; title and general lettering on coast chart No. 34, $\frac{1}{80000}$; notes and lettering on

coast chart No. 35, $\frac{1}{80000}$; on coast chart No. 8, $\frac{1}{800000}$; made corrections on coast charts 15, 16, and 17, and has done some miscellaneous work.

Mr. Ogilvie, letter engraver, has engraved the titles and notes on coast charts Nos. 40 and 41, $\frac{1}{80000}$; also the titles and some lettering on coast chart No. 8, $\frac{1}{800000}$; Portland harbor, Maine, $\frac{1}{20000}$; Port Royal entrance, S. C., $\frac{1}{60000}$; soundings on Patuxent river, Md., $\frac{1}{60000}$; notes and lettering on coast chart No. 108, $\frac{1}{80000}$; and some miscellaneous work.

Mr. Langran, letter engraver, has engraved title, notes, &c., on Lynn harbor, $\frac{1}{20000}$; Hempstead harbor, Long Island sound, $\frac{1}{20000}$; Sapelo sound, Georgia, $\frac{1}{30000}$; made additions and corrections for new edition of Muskeget channel, $\frac{1}{80000}$; notes on Port Royal, and considerable miscellaneous work.

Mr. Petersen, miscellaneous engraver, has engraved soundings, lettering, and notes on Portland harbor, Me., $\frac{1}{20000}$; title notes and lettering on Patuxent and St. Mary's rivers, Md., and Crescent City harbor, Cal., $\frac{1}{20000}$; notes and additional soundings on coast chart No. 91, $\frac{1}{80000}$; notes on Lynn harbor, $\frac{1}{20000}$; soundings on Hempstead harbor, $\frac{1}{20000}$, and some miscellaneous work.

Mr. Bartle, topographical engraver, has completed the topography of Rockport harbor, Mass., $\frac{1}{20000}$; and engraved that of Lynn harbor, Mass., $\frac{1}{20000}$; also the sanding of St. Mary's and Patuxent rivers, Md., $\frac{1}{60000}$; and Hempstead harbor, Long Island sound, $\frac{1}{20000}$; and the outlines of general coast chart No. X, $\frac{1}{400000}$, and coast chart No. 8, $\frac{1}{80000}$; besides being employed on progress sketches, diagrams, and miscellaneous work.

Mr. W. A. Thompson, topographical engraver, has engraved topography of St. George's sound, Florida, $\frac{1}{40000}$; and of York river, Va., (upper sheet,) $\frac{1}{60000}$; also marsh on coast chart No. 31, $\frac{1}{80000}$; and additions to the outlines on coast chart No. 35, $\frac{1}{80000}$; besides progress sketches and miscellaneous work.

Mr. Klakring, miscellaneous engraver, has been constantly employed on miscellaneous work, principally additions and corrections, both in topography and lettering.

Mr. Benner, miscellaneous engraver, has engraved topography on Crescent City harbor, $\frac{1}{20000}$, and the sketch of Rigolets, La., $\frac{1}{20000}$, besides progress and other sketches and some miscellaneous work.

Messrs. Sipe and J. G. Thompson, miscellaneous engravers, have been principally employed on diagrams, progress sketches, and miscellaneous work.

Mr. Wells, miscellaneous engraver, since his employment, has been practicing to acquire skill in stamping figures; also some miscellaneous work.

List of maps, preliminary charts, and sketches engraved or engraving during the year ending October 31, 1860, arranged in order of sections.

Name.	Scale.	Description.	Remarks.
SECTION I.			
Progress sketch A	1-400,000	Sketch	Engraved.
Do ..... A *bis*	1-600,000	......do	Do.
Preliminary sea-coast chart, No. 3	1-200,000	Preliminary chart	Engraving.
Preliminary sea-coast chart, No. 4	1-200,000	......do	Engraved.
Coast chart, No. 8, Seguin Island light to Kenebunkport.	1-80,000	Finished map and chart	Engraving.
Coast chart, No. 9, Cape Neddick, Me., to Cape Ann, Mass	1-80,000	......do	Do.
Coast chart, No. 11, Plymouth harbor to Hyannis harbor, Mass	1-80,000	......do	Do.
Coast chart, No. 12, Nantucket sound, Mass	1-80,000	......do	Do.
Coast chart, No. 13, Buzzard's bay and Martha's Vineyard	1-80,000	......do	Do.
Coast chart, No. 14, Point Judith to Block Island sound	1-80,000	......do	Do.
Portland harbor, (new edition)	1-20,000	Finished harbor chart	Do.
Rockport harbor, Mass	1-20,000	......do	Engraved.
Lynn harbor, Mass	1-20,000	......do	Do.
Muskeget channel, Mass., (new edition)	1-60,000	Finished chart	Do.
SECTION II.			
Progress Hudson river triangulation	1-400,000	Sketch	Engraved.
Coast chart, No. 15, eastern part of Long Island sound	1-80,000	Finished map and chart, (new edition.)	Do.
Coast chart, No. 16, middle of Long Island sound	1-80,000	......do	Do.
Coast chart, No. 17, Long Island sound, western sheet	1-80,000	......do	Do.
Coast chart, No. 19, Middle part, southern coast, Long Island sound	1-80,000	Finished map and chart, (additions.)	Do.
Coast chart, No. 21, New York bay and harbor	1-80,000	Finished map and chart,	Engraving.
Captain's island, east and west	1-20,000	Finished chart, (new edition.)	Engraved.
Hempstead harbor	1-20,000	Finished harbor chart	Do.
Hudson river, N. Y., (lower sheet)	1-60,000	Finished chart	Engraving.
SECTION III.			
Progress sketch C	1-400,000	Sketch	Engraved.
Coast chart, No 29, Green Run inlet to Little Machipongo inlet, Virginia	1-80,000	Finished map and chart	Engraving.
Chesapeake bay, No. 1, head of bay to Magothy river	1-80,000	......do	Do.
Chesapeake bay, No. 2, Magothy to the Hudson river	1-80,000	......do	Do.
Chesapeake bay, No. 3, Hudson to Potomac river, Md	1-80,000	......do	Do.
Chesapeake bay, No. 4, Potomac river to Pocomoke sound	1-80,000	......do	Do.
Chesapeake bay, No. 5, Pocomoke sound to York river	1-80,000	......do	Do.
Chesapeake bay, No. 6, York river to entrance of bay	1-80,000	......do	Do.
Patuxent river, Maryland	1-60,000	Preliminary chart	Engraved.
St. Mary's river, Maryland	1-60,000	Finished chart	Engraving.
Rappahannock river, Va., (lower sheet)	1-60,000	......do	Do.
York river Va., (upper sheet)	1-60,000	......do	Engraved.
SECTION IV.			
Progress sketch D	1-400,000	Sketch	Engraved.
Coast chart, No. 40, Albemarle sound, west	1-80,000	Finished map and chart	Do.
Coast chart, No. 41, Albemarle sound, east	1-80,000	......do	Do.
SECTION V.			
Progress sketch E	1-600,000	Sketch	Engraved.
Preliminary sea-coast chart, No. 14, Cape Roman to Tybee, Ga.	1-200,000	Preliminary chart	Engraving.
Charleston harbor, South Carolina	1-30,000	Finished map	Engraved.
Port Royal entrance, South Carolina	1-60,000	Preliminary chart	Engraving.
Bull's bay, South Carolina	1-60,000	......do	Engraved.
Sapelo sound, Georgia	1-30,000	......do	Engraving.
St. Simon's sound and Brunswick harbor	1-40,000	Preliminary chart, (new edition.)	Do.
SECTION VI.			
Progress sketch F	1-1,200,000	Sketch	Engraved.
Do...... F, (lower sheet)	1-400,000	......do	Do.
General coast chart, No. X, Florida reefs and keys, Cape Florida to Cape Sable	1-400,000	General coast chart	Engraving.
Coast chart, No. 68, Florida reefs, Key Biscayne to Carysfort reef	1-80,000	Finished map and chart	Do.
Coast chart, No 71, Florida reefs, Newfound Harbor key to Boca Grande key	1-80,000	......do	Do.
St. Augustine harbor, Florida	1-30,000	Preliminary chart	Do.

List of maps, preliminary charts, &c.—Continued.

Name.	Scale.	Description.	Remarks.
SECTION VII.			
Progress sketch G	1-600,000	Sketch	Engraved.
Eastern part of St. George's sound, Florida	1-40,000	Preliminary chart	Do.
Entrance to Pensacola bay, Florida	1-30,000	......do	Do.
SECTION VIII.			
Progress sketch H	1-600,000	Sketch	Engraved.
Coast chart, No. 91, Bonsecour's bay to Round island, Miss	1-80,000	Finished map and chart	Do.
Coast chart, No. 92, Round island to Grand island, Miss	1-80,000	......do	Engraving.
Rigolets, Louisiana	1-20,000	Preliminary chart	Engraved.
SECTION IX.			
Progress sketch I	1-600,000	Sketch	Engraved.
Coast chart, No. 108, Matagorda and Lavaca bays	1-80,000	Finished map and chart	Engraving.
SECTION X.			
Progress sketch J, (lower sheet)	1-600,000	Sketch	Engraved.
Do ...... J, (middle sheet)	1-600,000	......do	Do.
San Pedro harbor, California	1-30,000	Preliminary chart	Do.
San Francisco bay, California	1-50,000	Finished harbor chart	Do.
San Pablo bay, California	1-50,000	......do	Engraving.
Alden's reconnaissance, (western coast)	1-1,200,000	Reconnaissance, 1 sheet, (new edition.)	Engraved.
Cresent City harbor	1-20,000		Do.
Humboldt bay	1-30,000		Do.
SECTION XI.			
Progress sketch K	1-600,000	Sketch	Engraved.
Alden's reconnaissance, (western coast)	1-1,200,000	Reconnaissance, 2 sheets, (new edition.)	Do.
Washington sound, Washington Territory	1-200,000	Reconnaissance	Do.
MISCELLANEOUS.			
Sketch showing progress of Coast Survey	1-5,000,000	Sketch	Engraved.
Diagram of temperature in Florida straits		Diagram	Do.
Diagram of Girard College observations		......do	Do.
Diagram of Trowbridge's apparatus		......do	Do.
Diagram of Mitchell's apparatus		......do	Do.
Diagram of Magnetic observations		......do	Do.
Diagram of Gulf Stream observations, 1858		......do	Do.
Do...............do.........1860		......do	Do.
Gloucester harbor, Mass	1,20,000	Finished chart	Retouching and correcting.
Salem harbor, Mass	1-25,000	......do	Additions.
Wellfleet harbor, Mass	1-50,000	......do	Corrections
Boston harbor, Mass	1-40,000	......do	Retouching and correcting.
Plymouth harbor, Mass	1-20,000	......do	Corrections.
Nantucket harbor, Mass	1-20,000	......do	Retouching and correcting.
New London harbor, Long Island sound	1-20,000	......do	Corrections.
Sheffield and Cawkin's Island harbor, Long Island sound	1-20,000	......do	Retouching and corrections.
Oyster and Syosset bay, Long Island sound	1-30,000	......do	Do.
Black Rock and Bridgeport harbor, Long Island sound	1-20,000	......do	Do.
Mouth of Connecticut river	1-20,000	......do	Do.
Hell Gate, New York	1-5,000	......do	Additions.
Delaware bay and river, New Jersey, Pennsylvania, and Delaware.	1-80,000	......do	Do.
Mouth of Chester river, Maryland	1-60,000	......do	Retouching and correcting.
Cape Fear river, North Carolina	1-30,000	......do	Corrections.

List of Coast Survey maps, preliminary charts, and sketches engraved, geographically arranged.

1. LIST OF MAPS AND CHARTS ENGRAVED.

No.		
1.	Richmond's island, Maine	1–20,000
2.	Newburyport harbor, Massachusetts	1–20,000
3.	Ipswich and Annissquam harbors, Massachusetts	1–20,000
4.	Rockport harbor .... do	1–20,000
5.	Gloucester harbor .... do	1–20,000
6.	Salem harbor .... do	1–25,000
7.	Lynn harbor .... do	1–20,000
8.	Boston harbor—new edition, 1859 .... do	1–40,000
9.	Plymouth harbor .... do	1–20,000
10.	Provincetown harbor .... do	1–50,000
11.	Monomoy shoals .... do	1–40,000
12.	Bass River harbor .... do	1–40,000
13.	Wellfleet harbor .... do	1–50,000
14.	Nantucket harbor .... do	1–20,000
15.	Muskeget channel—new edition .... do	1–60,000
16.	Hyannis harbor .... do	1–30,000
17.	Harbor of Edgartown .... do	1–20,000
18.	Harbor of Wood's Hole .... do	1–20,000
19.	Harbor of Holmes's Hole and Tarpaulin Cove, Massachusetts	1–20,000
20.	Harbor of New Bedford, Massachusetts	1–40,000
21.	General chart of the coast from Gay Head to Cape Henlopen	1–400,000
22.	Fisher's Island sound, Connecticut	1–40,000
23.	Harbor of New London .... do	1–20,000
24.	Mouth of Connecticut river . do	1–20,000
25.	Harbor of New Haven, Connecticut—new edition, 1852	1–30,000
26.	Harbor of Black Rock and Bridgeport, Connecticut—new edition, 1852.	1–20,000
27.	Harbors of Sheffield and Cawkin's island, Connecticut—new edition, 1852	1–20,000
28.	Huntington bay, New York	1–30,000
29.	Oyster bay or Syosset harbor, New York	1–30,000
30.	Harbors of Captain's island, East and West Connecticut	1–20,000
31.	Hempstead harbor, Long Island, New York	1–20,000
32.	Hart and City island and Sachem's Head harbor, New York	1–10,000 1–20,000
33.	Hell Gate, New York	1–5,000
34.	Long Island Sound—east	1–80,000
35.	Do .... do .... middle	1–80,000
36.	Do .... do .... west	1–80,000
37.	New York bay and harbor, and the environs, New York, No. 1	1–30,000
38.	Do ...... do ...... do ...... do ...... do ..... No. 2	1–30,000
39.	Do ...... do ...... do ...... do ...... do ..... No. 3	1–30,000
40.	Do ...... do ...... do ...... do ...... do ..... No. 4	1–30,000
41.	Do ...... do ...... do ...... do ...... do ..... No. 5	1–30,000
42.	Do ...... do ...... do ...... do ...... do ..... No. 6	1–30,000
43.	Do ...... do ...... do ...... do ...... do	1–80,000
44.	Western part south coast of Long Island, New York	1–80,000

No. 45.	Middle part south coast of Long Island, New York	1–80,000
46.	Eastern part....do.............do.........do	1–80,000
47.	Little Egg harbor, New Jersey	1–30,000
48.	Delaware bay and river—sheet No. 1, Delaware	1–80,000
49.	Do......do..........do No. 2, Delaware, New Jersey, and Pennsylvania	1–80,000
50.	Delaware bay and river—sheet No. 3	1–80,000
51.	Patapsco river, Maryland	1–60,000
52.	Harbor of Annapolis and Severn river	1–60,000
53.	Mouth of Chester river, Maryland	1–40,000
54.	Entrance to York river, Virginia	1–60,000
55.	Pasquotank river, North Carolina	1–60,000
56.	Albemarle sound, North Carolina—sheet No. 1	1–80,000
57.	Do....do...........do.........do No. 2	1–80,000
58.	Beaufort harbor .... .. do	1–20,000
59.	Charleston harbor, South Carolina—new edition, 1858	1–30,000
60.	Key West harbor and approaches, Florida	1–50,000
61.	Eastern part St. George's sound, ...do	1–40,000
62.	Entrance to Mobile bay, Alabama	1–40,000
63.	Mobile bay, Alabama	1–80,000
64.	Cat and Ship Island harbors, Mississippi	1–40,000
65.	Coast chart No. 91, (preliminary edition)	1–80,000
66.	Entrance to Galveston bay, Texas, (new edition, 1856)	1–40,000
67.	San Diego bay, California	1–40,000
68.	Entrance to San Francisco bay, California	1–50,000

2. List of Preliminary Charts and Sketches engraved.

1.	Alden's rock, Maine	1–1,000
2.	Eggemoggin reach, Maine	1–20,000
3.	Kennebec river......do	1–30,000
4.	Portland harbor......do	1–20,000
5.	Portland harbor, (commissioners' line,) Maine	1–10,000
6.	York River harbor, Maine	1–20,000
7.	Portsmouth harbor, New Hampshire	1–20,000
8.	Stellwagen's Bank—2d edition—Massachusetts	1–400,000
9.	Boston bay......................do	1–175,000
10.	Current chart, Boston bay........do	1–100,000
11.	Minot's ledge.......................do	1–10,000
12.	Sea-coast of United States, No. 4, south part of Massachusetts	1–200,000
13.	Nantucket shoals, Massachusetts, (new edition)	1–200,000
14.	Tidal currents, Nantucket shoals, Massachusetts	1–300,000
15.	Sow and Pigs reef.....................do	1–240 & 1–20,000
16.	Tidal currents, Long Island, New York	1–800,000
17.	Pot rock and Ways reef........do	
18.	Hudson river, lower sheet......do	1–60,000
19.	Buttermilk channel............do	1–5,000
20.	Beacon ranges, New York harbor	1–40,000
21.	Romer shoals and Flynn's knoll, New York	1–40,000
22.	Changes in Sandy Hook, New Jersey	1–10 & 1–40,000

No. 23.	Sea-coast of Delaware, Maryland, and part of Virginia	1–200,000
24.	Delaware and Chesapeake bays	1–400,000
25.	Chesapeake bay, (upper series,) Sheet No. 1	1–80,000
26.	Do do do No. 2	1–80,000
27.	Do do do No. 3	1–80,000
28.	Patuxent river, Maryland	1–60,000
29.	St. Mary's river do	1–60,000
30.	Chincoteague inlet, Virginia	1–40,000
31.	Sea-coast of Virginia and entrance to Chesapeake bay, Virginia	1–200,000
32.	James river, (upper sheet) do	1–40,000
33.	Rappahannock river No. 1 do	1–20,000
34.	Do do No. 2 do	1–20,000
35.	Do do No. 3 do	1–20,000
36.	Do do No. 4 do	1–20,000
37.	Do do No. 5 do	1–60,000
38.	Do do No. 6 do	1–60,000
39.	York river, from King's creek to West Point do	1–60,000
40.	Wachapreague, Machipongo, and Metompkin inlets do	1–40,000
41.	Ship and Sand Shoal inlets do	1–40,000
42.	Entrance to Chesapeake bay do	1–100,000
43.	Cape Charles and vicinity do	1–80,000
44.	Cherrystone inlet do	1–40,000
45.	Pungoteague creek do	1–40,000
46.	Fishing or Donoho's battery, Maryland do	1–80,000
47.	Albemarle sound, North Carolina	1–200,000
48.	Diagrams showing the effect of the wind in elevating and depressing the water in Albemarle sound	
49.	Hatteras shoals, North Carolina	1–20,000
50.	Cape Hatteras do	1–20,000
51.	Hatteras inlet do (fourth edition)	1–20,000
52.	Ocracoke inlet do	1–40,000
53.	Sea-coast of North Carolina from Hatteras to Ocracoke	1–200,000
54.	Wimble shoals, North Carolina	1–80,000
55.	Beaufort harbor do	1–20,000
56.	New river and bar do	1–15,000
57.	Frying Pan shoals do	1–120,000
58.	Cape Fear river and New inlet, North Carolina	1–40,000
59.	Entrance to Cape Fear river, (new edition,) North Carolina	1–30,000
60.	Cape Fear river from Federal Point to Wilmington, North Carolina	1–30,000
61.	Gulf Stream explorations, 1853	1–5,000,000
62.	Diagrams, Gulf Stream explorations, 1853	
63.	Gulf Stream explorations, 1854	1–5,000,000
64.	Diagrams, Gulf Stream explorations, 1854	
65.	Gulf Stream explorations, 1855	1–5,000,000
66.	Co-tidal lines, Atlantic coast	1–10,000,000
67.	Diagram of secular variation of magnetic dip, Atlantic coast	
68.	Cape Roman shoals, South Carolina	1–100,000
69.	Sea-coast of the United States, No. 14, South Carolina	1–200,000
70.	Winyah bay and Cape Roman shoals do	1–100,000
71.	Winyah bay and Georgetown harbor do	1–40,000

No. 72.	Bull's bay .... South Carolina	1–40,000
73.	Comparative chart, Maffitt's channel .... do ...... (new edition) ..	1–5,000
74.	Maffitt's channel, sections .... do	
75.	North Edisto river, (new edition) ...... do	1–50,000
76.	Romerly marshes .... do	1–10,000
77.	Savannah River entrance, Georgia	1–30,000
78.	Savannah city, Front and Back rivers, Georgia	1–20,000
79.	Savannah river .... do	1–40,000
80.	Sapelo sound .... do	1–30,000
81.	Doboy bar and inlet .... do	1–40,000
82.	St. Simon's sound and Brunswick harbor .. do	1–40,000
83.	St. Andrew's shoal .... do	1–60,000
84.	St. Mary's bar, and Fernandina harbor, Florida, comparative chart ...	1–20,000
85.	St. Mary's river and Fernandina harbor ... do	1–20,000
86.	St. John's river, from entrance to Brown's creek, Florida	1–25,000
87.	Mosquito inlet .... do	1–40,000
88.	Cape Cañaveral .... do	1–60,000
89.	Florida reefs .... do	1–200,000
90.	Turtle harbor .... do	1–40,000
91.	Beacons on Florida reefs .... do	
92.	Coffin's Patches .... do	1–20,000
93.	Key Biscayne, Cape Sable and bases .... do	1–60,000 & 1–400,000
94.	Legaré anchorage .... do	1–20,000
95.	Key West harbor, (second edition) .... do	1–100,000
96–102.	Key West tidal diagrams .... do	
103.	Rebecca shoals .... do	1–600,000
104.	Reconnaissance vicinity of Cedar Keys .... do	1–300,000
105.	Channel No. 4, Cedar Keys .... do	1–30,000
106.	Cedar Keys and approaches .... do	1–50,000
107.	Ocilla river .... do	1–20,000
108.	St. Mark's bar and channel .... do	1–40,000
109.	Middle or main and western entrances, St. George's sound, Florida ...	1–80,000
110.	St. Andrew's bay .... do	1–40,000
111.	Entrance to Pensacola bay .... do	1–30,000
112.	Sea-coast of part of Alabama and Mississippi	1–200,000
113.	Mobile bay, (second edition,) Alabama	1–200,000
114.	Horn Island pass and Grand bay, Mississippi	1–300,000
115.	Do .... do ...... do .... (new edition)	1–40,000
116.	Pascagoula river .... do	1–20,000
117.	Biloxi bay .... do	1–40,000
118–127.	Cat island tidal diagrams .... do	
128.	Pass Christian .... do	1–40,000
129.	Delta of the Mississippi, Louisiana	1–60,000
130.	Gulf of Mexico, with profiles of deep-sea soundings, (new edition)	1–2,400,000
131.	Barataria Bay entrance, Louisiana	1–30,000
132.	Pass Fourchon .... do	1–10,000
133.	Timballier Bay entrance .. do	1–20,000
134.	Isle Dernière, or Ship Island shoals, Louisiana	1–80,000
135.	Atchafalaya bay .... do	1–50,000
136.	Entrance to Vermilion bay and Calcasieu river, Louisiana	1–30,000 & 1–40,000

No. 137. Sabine Pass, Texas 1–40,000
138. Sea-coast of Texas, from Galveston south 1–200,000
139. Sea-coast of the United States, No. 31, part of Texas 1–200,000
140. San Luis Pass, Texas 1–20,000
141. Aransas Pass, Texas, (2d edition) 1–30,000
142. Entrance to Brazos river, Texas 1–10,000
143. Entrance to Rio Grande river, Texas 1–20,000
144. Diagrams of heights and lunitidal intervals of diurnal and semi-diurnal tides in the Gulf of Mexico ....
145, 146. Co-tidal lines, Gulf of Mexico, (2 plates) ....
147. Type curves ...... do ....
148. Wind curves, Cat island ....
149. Alden's reconnaissance, Western Coast; lower sheet, San Francisco to San Diego, (new edition,) California 1–1,200,000
150. Cortez bank .... 1–100,000 & 1–1,200,000
151. San Diego entrance, (new edition,) California .... 1–150,000 & 1–25,000
152. Geological map of San Diego, California 1–1,608,228
153. Catalina harbor 1–15,000
154. San Pedro anchorage and vicinity of Santa Barbara, California, 1–20,000 & 1–40,000
155. Anacapa island, (sketch,) California ....
156. Anacapa island and east end of Santa Cruz island, California 1–30,000
157. Prisoner's harbor, Cuyler's harbor, and north anchorage San Clemente island, California 1–20,000
158. Santa Barbara, California 1–20,000
159. Eastern entrance to Santa Barbara channel, California 1–80,000
160. San Simeon, Santa Cruz, San Luis Obispo, and Coxo harbors, California .... 1–20,000 & 1–40,000
161. Point Conception, California 1–40,000
162. Point Piños .... do 1–20,000
163. Monterey harbor ..... do 1–40,000
164. Monterey bay .... do 1–60,000
165. Geological map of Monterey, California 1–150,000
166. Santa Cruz and Año Nuevo harbors, California .... 1–1,200,000 & 1–40,000
167. San Pedro harbor .... do 1–20,000
168. Entrance to San Francisco bay .... do 1–400,000
169. San Francisco city, (new edition) .... do 1–10,000
170. Geological map of San Francisco .... do 1–150,000
171. South Farrallone island .... do ....
172. Tidal diagrams, Rincon Point .... do ....
173. Pulgas base 1–400,000
174. San Antonio creek .... do 1–20,000
175. Mare Island straits 1–30,000
176. Alden's reconnaissance, Western Coast: middle sheet, San Francisco to Umpqua river, California and Oregon 1–1,200,000
177. McArthur's reconnaissance, Western Coast, from Monterey to mouth of Columbia river—sheet No. 1, (3d edition) ....
178. McArthur's reconnaissance, Western Coast, from Monterey to mouth of Columbia river—sheet No. 2, (3d edition) ....
179. McArthur's reconnaissance, Western Coast, from Monterey to mouth of Columbia river—sheet No. 3, (3d edition) ....

No. 180.	Alden's reconnaissance, Western Coast—northern sheet	1–1,200,000
181.	Point Reyes and Drake's bay, California	1–40,000
182.	Geological map of Point Reyes, California	
183.	Humboldt bay, (new edition) do	1–30,000
184.	Trinidad bay do	1–20,000
185.	Shelter cove, Mendocino City, Crescent City harbors, and Port Orford or Ewing harbor, California and Oregon	1–20,000
186.	Crescent City harbor, California	1–20,000
187.	Umpqua river, Oregon	1–20,000
188.	Mouth of Columbia river, Oregon, (2d edition)	1–40,000
189.	Do do do	1–200,000
190.	Entrance to Columbia river do	1–40,000
191.	Tidal diagrams, Rincon Point, San Diego, and Astoria, California and Oregon	
192.	Co-tidal lines of Pacific coast	1–10,000,000
193.	Cape Disappointment, Washington Territory	1–20,000
194.	Shoalwater bay do	1–80,000
195.	Alden's reconnaissance, Western Coast, from Gray's harbor to Admiralty inlet, Washington Territory	1–600,000
196.	Grenville harbor, Washington Territory	1–20,000
197.	Cape Flattery and Nèe-ah harbor, do	1–40,000
198.	False Dungeness do	1–30,000
199.	New Dungeness do	1–40,000
200.	Washington sound do	1–200,000 & 1–600,000
201.	Port Townshend, (new edition) do	1–40,000
202.	Duwamish bay and Seattle harbor do	1–40,000
203.	Smith's or Blunt's island do	1–20,000
204.	Port Ludlow do	1–20,000
205.	Port Gamble do	1–20,000
206.	Olympia harbor do	1–20,000
207.	Steilacoom harbor do	1–30,000
208.	Bellingham bay do	1–40,000
209.	Blakely harbor do	1–10,000
210.	Semi-ah-moo bay do	1–30,000
211.	Base apparatus	
212.	Self-registering tide-gauge	
213.	Craven's current indicator	
214.	Craven's specimen box for deep-sea soundings	
215.	Mitchell's sea-coast tide-gauge	
216.	Figures to illustrate Appendix No. 33, 1854	
217.	Diagrams of secular variation in magnetic declination, 1855	
218.	Lines of equal magnetic declination	1–1,500,000
219.	Boutelle's scaffold for stations, and Farley's signals	
220.	Boutelle's apparatus for measuring preliminary bases	
221.	Diagrams to illustrate earthquake waves at San Diego and San Francisco	
222.	Diagrams of secular variation in magnetic declination, 1856	
223.	Sands's gas-pipe tripod	
224.	Sands's specimen box for deep-sea soundings and revolving heliotrope	
225.	Map of magnetic declination	

Report of Mr. George Mathiot, in charge of the Electrotype Division.

UNITED STATES COAST SURVEY OFFICE, *September* 17, 1860.

I respectfully present the following report of the operations in this division since the date of my last annual report, September 17, 1859.

By the electrotype process we have made fifty-one plates; of this number, nineteen were in alto and thirty-two in basso. We have also made four plates for other departments of the government. One plate has been extended in size by the electrotype process.

In my last annual report I announced that the reducing of the charts by *photography* was, at last, after years of experimenting, in successful operation in the office. The beginning thus announced has proved the commencement of a very important and valuable branch of the office-work. During the year the photographic reduction of charts has been steadily in use, and before long will entirely supersede hand reducing. In December last the first effort at the regular employment of photography in the office was made. Mr. W. H. Gardner was then detailed to assist me by making tracings from plane-table sheets, and Mr. E. Hergesheimer in preparing the projections and overseeing the work in all matters relating to geographical positions and correct delineations, where the experience of a skilful draughtsman is required. In February this force was increased by the addition of Mr. F. W. Maedel to assist in tracing. Under the arrangement thus made seventy-nine plane-table sheets were traced and photographed by the first day of July last, when the success of the photographic method was deemed so certain that it was established as a regular office method, and the preparation of tracings, and all matters relating to positions, delineations, &c., became the duty of the Drawing Division, the photographing of the tracings being assigned to this division as part of its *regular* duty. Under this last arrangement the photograph has increased in utility and value. Some of the finest charts of the survey have been reduced by it, and are now being engraved. I append a table of the photographs made since December 12, from which it will be seen that there have been

reduced not less than fifty-five sheets, comprising the major part of eight coast charts. Coast chart No. 29, which I stated in my last annual report as having been successfully reduced and in the hands of the engraver, is in the course of completion. The reduction of coast chart No. 21, (New York bay and harbor,) which I also announced as being partly made, has been retraced, in order to make it conform to the rules for tracing which were established for giving uniformity to the charts. The San Pablo chart, which I reported last year as being reduced, was laid aside for the same reason.

The methods employed in the photographic reductions are mainly the same as stated in my last report, excepting that, instead of furnishing the reduction to the engraver on *paper*, it is now given on *glass*, or what is termed a "collodion positive." By the use of glass all the errors and difficulties arising from hygrometric action are avoided. Instead of a sheet of gelatine paper to transfer the design from the reduction to the copper, a plate of mica can be used over quite a large portion of the design on the glass, with the certainty of conformity with the projection on the copper; the time saved by avoiding the delays from hygrometric changes, and in making small transfers, being of great importance in the cost and time of getting out the chart. In this way the work of coast chart No. 9 (Kennebunkport to Cape Ann, Mass.,) has been very rapidly executed.

Instead of furnishing the engraver, as formerly, with a finished design of the chart, together with the original or plane-table sheets to assist him in entering it in the copper, he is now furnished with the outlines only, and of but a portion of the chart at a time. This outline is the photograph, (the collodion positive,) on glass, of the tracing, and has the latitude and longitude lines numbered to conform with the projections on the copper plate. As there is nothing on the glass plate but what is to be transferred to the copper, the work is thus unerringly entered in the copper. While the engraver is cutting in the outlines, a paper print from the negative of the tracing is placed in the hands of the draughtsman, who indicates the filling of the outlines merely by *colors*, instead of endeavoring, as formerly, to present the finished appearance of the chart by elaborately drawing the topographical signs for wood, marsh, &c. Using these for such parts only as are too small to exhibit the colors plainly, the engraver enters the filling from samples of wood, marsh, &c. In this way uniformity is produced in the appearance of the charts, and errors prevented. Advantage of this mechanical method is taken further to assist the engraver by supplying him with an enlarged photographic print of the outline, in which the minute forms he has to engrave, and the smaller patches of color, will be seen at a glance. This enlarged print is generally on a scale double that of the chart scale. The advantages incidental to the photographic method have gained for it high favor with the engravers.

Of the relative cost of the photographic and hand methods of reducing an exact estimate cannot yet be made; but from the work of the past year I think the photographic method will turn out to cost about one-sixth of the hand-work. Of the comparative value of the two methods, I can say that there is no doubt of the very great superiority of the photographic method; for it turns out that so great are the *incidental* advantages in the process of engraving that the savings from these alone will thrice repay the cost of the photographic reduction.

With regard to the accuracy of the photographic reductions, nothing remains to be desired; experience having shown that they are superior to the hand reductions in this respect. Fears were at first entertained that in engraving the chart from detached portions of the reductions non-conformity of adjacent parts would arise; but the experience of the year has shown that the junctions of the adjacent sheets can be made as well on the tracing as on the reduced drawing, and consequently no overlapping or ill-fitting of the photographs has appeared.

During the year the development of photography has been closely watched, with a view to the further application of the art to the purposes of the survey. The processes of photolithography and carbon printing have received especial attention; but little *experimenting*, how-

ever, has been done in these, the large amount of photographic work executed having precluded this, and left but little time for investigation except in the direct line of the work. Several practical applications of photo-lithography have lately been made, both in this country and in Europe; yet all the specimens exhibited have indicated that the art is still too crude to be employed for the purposes of the survey. The great prospect of celerity of execution which this new art holds out still makes it attractive, and it should by no means be neglected by the survey.

Though I think the photo-lithograph too imperfect at present to be used for the publication of our charts, I still hold the opinion expressed in my last report, that the ordinary photographic process may be advantageously used for the publication of some of our smaller charts and sketches. I had hoped that a trial of this would have been made in the past year, and still hope that the office will order the experiments to be made.

During the year I have been assisted by Mr. D. Hinkle. Again it becomes my duty to commend him for his application to the work. Excepting the arrangements for making the tracings noticed above, there has been no additional force in this division; and the large amount of photographing executed, in addition to our former regular duties, is in a great measure the result of his industry.

The following summary shows the number of plane-table sheets reduced by photography for the charts to which the material on them applies:

Coast chart No. 9	8 sheets.
Do 11	1 sheet.
Do 21	16 sheets.
Do 47	3 "
Do 48	4 "
Do 54	2 "
Do 81	7 "
Chart of San Francisco bay	12 "

List of plates electrotyped in alto.

Name of chart.	No. made.	Name of chart.	No. made.
Portland harbor	1	Captain's island, east and west	1
Sapelo sound	1	Chesapeake bay, No. 4	1
Chart showing progress of the survey	1	Boston harbor	1
New Haven harbor	1	Hampstead harbor	1
Washington sound	1	Gulf Stream diagrams, plate No. 1	1
Sea-coast chart, No. 4	1	Gulf Stream diagrams, plate No. 2	1
San Francisco bay	1	Muskeget channel	1
Rockport harbor	1	Part of general coast chart, No. 11	1
Crescent City harbor	1		

List of plates electrotyped in basso.

Name of chart.	No. made.	Name of chart.	No. made.
Wood's Hole	1	Sea-coast chart, No. 4	1
Annisquam and Ipswich harbors	2	San Francisco bay	1
Provincetown harbor	1	Rockport harbor	1
Patapsco river	1	San Diego bay	1
Muskeget channel	1	York river entrance	1
Cape Fear river	1	Crescent City harbor	1
Port Gamble	1	Captain's island, east and west	1
Chart showing progress of the survey	1	Chesapeake bay, No. 4	2
Map of the World	1	Boston harbor	1
Entrance to Brazos river	1	Hampstead harbor	1
Atchafalaya bay	1	Gulf Stream diagrams, plate No. 1	1
Sapelo sound	1	Gulf Stream diagrams, plate No. 2	1
Charleston harbor	1	Washington sound	1
Mare Island straits	1	Romerly marshes	1

Report of Lieutenant J. R. Smead, U. S. A., in charge of the Miscellaneous Division.

COAST SURVEY OFFICE, *Washington, October* 1, 1860.

The Miscellaneous Division, consisting of the printing office, the map room, and office for distribution of the maps and charts and of the Coast Survey reports, has continued under my charge since the date of my last report.

The records of the division are kept by Mr. V. E. King, who also has charge of the map room, and distribution of maps, charts, and sketches, and Coast Survey reports, assisted by Mr. T. B. Alexander from October 1 until April 23, when he resigned his position, and was succeeded by Mr. C. C. Callan, who was transferred to the Engraving Division July 1; since that date Mr. W. M. Maynadier has assisted Mr. King.

In addition to these duties, Mr. King assists in the clerical duties in the office of the assistant in charge. In the Miscellaneous Division his services are invaluable, from his intimate acquaintance with the details of the duty and his steady application to its performance.

Mr. W. Mertz backs and stretches the printing paper, and backs and repairs plane-table and other sheets for use in the Drawing Division of the office. He has given entire satisfaction during the year.

In the printing office, Mr. Rutherdale, as printer, with his assistant, Mr. Barrett, have been industrious, and very constant in their attendance.

I have caused to be prepared, and herewith respectfully submit, a statement of Coast Survey maps, charts, and sketches distributed during the year; also a statement of the distribution of Coast Survey reports, and of the maps, charts, sketches, and miscellaneous matter printed, since the date of the last annual report.

List of Coast Survey maps, charts, and sketches distributed during the year, for sale, use of office, and gratuitously.

Names of maps.	Turned over for sale.	For use of office.	Gratuitously distributed.	Total.
Richmond Island harbor	10	1	32	43
York River harbor	15	1	33	49
Newburyport harbor	22	1	38	61
Ipswich and Annisquam harbors	15	....	74	89
Gloucester harbor	....	3	46	49
Salem harbor	....	6	30	36
Wellfleet harbor	5	2	38	45
Boston harbor, $\frac{1}{40000}$	124	11	95	230
Boston harbor, $\frac{1}{175000}$	56	2	33	91
Plymouth harbor	15	3	93	111
Sea-coast of United States from Plymouth, Mass., to Saughkonnet river, R. I.	12	10	37	59
Provincetown harbor	21	4	94	119
Harbor of Wood's Hole	33	....	50	83
Nantucket harbor	1	....	10	11
Harbor of Hyannis	....	....	36	36
Harbors of Holmes's Hole and Tarpaulin Cove	15	3	24	42
General coast chart from Gay Head to Cape Henlopen	20	8	33	61
Long Island sound, eastern sheet	7	6	72	85
Long Island sound, middle sheet	5	10	72	87
Long Island sound, western sheet	5	7	71	83
Fisher's Island sound	20	4	29	53
Harbor of New London	45	10	28	83
Mouth of Connecticut river	20	....	26	46
Harbor of New Haven	20	1	20	41
Harbors of Black Rock and Bridgeport	10	....	25	35
Huntington bay	30	....	25	55
Harbors of Sheffield and Cawkins islands	16	1	24	41
Oyster bay, or Syosset harbor	20	1	25	46
Hart and City islands and Sachem's Head harbor	10	....	22	32
Hell Gate	1	3	45	49
New York bay and harbor and the environs, $\frac{1}{30000}$	11	1	19	31
New York bay and harbor and the environs, $\frac{1}{80000}$	176	28	68	272
Eastern part of south coast of Long Island	10	3	54	67
Middle part of south coast of Long Island	7	3	47	57
Western part of south coast of Long Island	10	3	47	60
Delaware bay and river, upper sheet	118	7	39	164
Delaware bay and river, middle sheet	118	14	39	171
Delaware bay and river, lower sheet	118	8	41	167
Patapsco river	60	11	49	120
Mouth of Chester river	9	1	24	34
Harbor of Annapolis and Severn river	9	6	42	57
York River entrance	10	6	70	86
Pasquotank river	11	1	27	39
Beaufort harbor	11	6	72	89
Cape Fear River entrances	17	6	68	91
Cape Fear river from Federal Point to Wilmington	22	4	31	57

LIST OF COAST SURVEY MAPS, &c.—Continued.

Names of maps.	Turned over for sale.	For use of office.	Gratuitously distributed.	Total.
Charleston harbor	15	2	28	45
Cat and Ship Island harbors	21	2	26	49
Mobile bay	39	14	56	109
Mobile Bay entrance	35	5	27	67
Galveston entrance	10		20	30
Key West harbor and approaches	21	10	36	67
Pensacola harbor	22	9	56	87
San Diego bay	6	9	58	73
Entrance to San Francisco bay		3	113	116
Sketches of—Kennebec River entrance		4	3	7
Minot's ledge	22		6	28
Comparative map of Hudson river		1	1	2
Little Egg harbor		2	8	10
Delaware and Chesapeake bays	67	12	24	103
Sea-coast of Delaware, Maryland, and part of Virginia		2	6	8
Chincoteague inlet	6		6	12
Sea-coast of Virginia and entrance to Chesapeake bay	54	5	14	73
Norfolk harbor		3	16	19
Hampton Roads		9	16	25
Albemarle sound	24	2	17	43
Comparative chart, Beaufort harbor			1	1
Ocracoke inlet		3	5	8
Hatteras and Ocracoke inlets			2	2
Comparative chart of Cape Fear entrances			1	1
New inlet, Cape Fear river			1	1
Frying Pan shoals			2	2
New river and bar	1	1	4	6
Sea-coast of South Carolina			1	1
North Edisto river			1	1
St. Helena sound			2	2
Winyah bay and Georgetown harbor	7		7	14
Entrance to Savannah river	91	6	11	108
Savannah city, Front and Back rivers	91	5	10	106
St. Simon's sound and Brunswick harbor	7	5	10	22
Romerly marshes	6		6	12
St. Mary's bar and Fernandina harbor	3		6	9
St. Mark's bar	6	3	6	15
St. John's river from entrance to Brown's creek	15	2	10	27
Comparative chart, St. John's river			2	2
Waccasassa bay			2	2
Cedar keys	1	6	12	19
Apalachicola river		3	3	6
St. Andrew's bay	7		9	16
Sea-coast of Alabama and Mississippi	22	4	13	39
St. Louis bay and Shieldsboro' harbor		2	1	3
Biloxi bay		1	8	9
Mississippi City harbor		1	2	3

LIST OF COAST SURVEY MAPS, &c.—Continued.

Names of maps	Turned over for sale.	For use of office	Gratuitously distributed.	Total.
Sketches of—Grand Island Pass	....	1	2	3
Delta of Mississippi	....	5	9	14
Ship Island shoal	....	3	9	12
Reconnaissance of coast of Texas	....	....	3	3
Matagorda bay	....	....	3	3
San Luis Pass	....	....	1	1
Reconnaissance of the western coast of the United States from San Diego to San Francisco	13	10	20	43
Reconnaissance of the western coast of the United States from San Francisco to Umpqua river	13	10	20	43
Reconnaissance of the western coast of the United States from Umpqua river to the boundary	13	11	20	44
Cortez bank	....	....	6	6
Prisoner's, Cuyler's, and San Clemente harbors	5	....	6	11
San Clemente island, southeast end	....	....	6	6
Santa Barbara	5	....	10	15
Anacapa island	6	....	11	17
San Simeon, Santa Cruz, San Luis Obispo, and Coxo	5	....	9	14
Santa Cruz and Año Nuevo	5	....	10	15
San Pedro harbor	5	1	6	12
Monterey harbor	5	....	8	13
San Francisco city	7	9	31	47
San Pablo bay	....	....	6	6
Humboldt bay	....	....	8	8
Trinidad bay	5	1	8	14
Port Orford, Shelter Cove, Mendocino City, and Crescent City harbors	5	....	9	14
Entrance to Umpqua river	5	....	9	14
Entrance to Columbia river	6	1	5	12
Shoalwater bay	....	1	8	9
Reconnaissance from Gray's harbor to Admiralty inlet	5	....	9	14
Cape Flattery and Nèe-ah harbor	....	....	10	10
False Dungeness harbor	5	1	3	9
Port Townsbend	....	....	12	12
Washington sound	....	7	50	57
Port Ludlow	6	....	12	18
Port Gamble	....	....	10	10
Blakely harbor	6	....	10	16
Bellingham bay	6	....	10	16
Steilacoom harbor	6	....	10	16
Semi-ah-moo bay	....	....	9	9
Measurement of Epping base	....	18	1	19
Eggemoggin reach	4	....	4	8
Current chart, Boston harbor	4	4	4	12
Stellwagen's bank	1	....	1	2
Sow and Pigs reef	3	....	3	6
Romer shoal and Flynn's knoll	....	....	1	1

LIST OF COAST SURVEY MAPS, &c.—Continued.

Names of maps.	Turned over for sale.	For use of office.	Gratuitously distributed.	Total.
Sketches of—Changes in Sandy Hook	9	....	5	14
Wachapreague, Machipongo, and Metomkin inlets	8	....	5	13
Ship and Land Shoal inlets	....	....	2	2
Cherrystone inlet	1	....	2	3
Pungoteague creek	8	....	6	14
Fishing or Donoho's battery	8	....	4	12
Sea-coast of North Carolina	....	....	1	1
Hatteras shoals	....	....	1	1
Hatteras inlet	....	2	2	4
Wimble shoals	....	....	1	1
Winyah bay and Cape Roman shoals	1	....	2	3
Bull's bay	....	1	2	3
St. Andrew's shoals	6	....	7	13
Mosquito inlet	6	2	6	14
Cape Cañaveral	4	1	7	12
Rebecca shoal	....	....	6	6
Turtle harbor	1	1	6	8
Coffin's Patches	....	1	6	7
Entrance to St. George's sound	....	3	5	8
Horn Island Pass	1	1	3	5
Pascagoula river	....	....	2	2
Pass Christian	6	....	4	10
Pass Fourchon	6	....	3	9
Aransas Pass	5	....	3	8
Sabine Pass	....	....	2	2
Entrance to Rio Grande river	1	1	2	4
San Pedro anchorage	....	....	7	7
Mare Island straits	6	....	8	14
Point Conception	....	....	5	5
Point Piños	....	....	7	7
Point Reyes and Drake's bay	5	....	7	12
Cape Hancock	....	....	7	7
Duwamish bay and Seattle harbor	6	....	7	13
Diagrams to illustrate the secular variations in the magnetic declination	6	....	86	92
Lines of equal magnetic declination	1	....	15	16
Lines of equal magnetic dip and horizontal intensity	6	....	94	100
Map of the world on a polyconic development of the sphere	6	15	41	62
Diagrams of wind, western coast	....	20	57	77
Diagrams of wind, Atlantic coast	....	....	21	21
Deep-sea sounding apparatus, (Berryman's)	....	....	16	16
Diagrams, difference of longitude between Savannah and Fernandina	....	....	11	11
Co-tidal lines, Atlantic coast	....	20	21	41
Total	2,145	493	3,599	6,237

Distribution made during the year of Reports of the United States Coast Survey for the years **1851, 1852, 1853, 1854, 1855, 1856, 1857,** *and* **1858.**

Names of States, &c.	Rept. of 1851.			Rept. of 1852.			Rept. of 1853.			Rept. of 1854.			Rept. of 1855.			Rept. of 1856.			Rept. of 1857.			Rept. of 1858.		
	Individuals.	Institutions.	Total.	Individuals.	Institutions.	Total.	Individuals.	Institutions.	Total.	Individuals.	Institutions.	Total.	Individuals.	Institutions.	Total.	Individuals.	Institutions.	Total.	Individuals.	Institutions.	Total.	Individuals.	Institutions.	Total.
Maine	....	....	....	....	....	....	....	....	....	1	....	1	1	....	1	2	....	2	7	....	7	78	4	82
New Hampshire	1	....	1	1	....	1	1	....	1	....	....	....	....	....	....	....	....	....	1	....	1	46	3	49
Vermont	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	....	....	....	6	....	6	29	1	30
Massachusetts	2	....	2	2	3	5	5	3	8	5	3	8	4	3	7	9	3	12	32	3	35	238	25	263
Rhode Island	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	....	....	....	....	....	....	34	3	37
Connecticut	....	....	....	1	....	1	4	....	4	3	....	3	2	....	2	3	....	3	3	....	3	79	6	85
New York	4	....	4	7	....	7	10	....	10	10	....	10	17	....	17	22	....	22	51	....	51	373	34	407
New Jersey	....	1	1	....	1	1	2	1	3	1	1	2	1	1	2	2	1	3	10	....	10	80	6	86
Pennsylvania	1	....	1	2	....	2	1	1	2	2	1	3	2	....	2	3	1	4	26	1	27	266	25	291
Delaware	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	2	....	2
Maryland	....	....	....	....	....	....	....	....	....	2	....	2	3	....	3	3	....	3	16	....	16	93	3	96
District of Columbia	2	....	2	2	....	2	7	....	7	7	....	7	9	....	9	23	....	23	34	....	34	141	....	141
Virginia	1	....	1	....	....	....	2	....	2	2	....	2	2	....	2	2	....	2	8	....	8	95	2	97
North Carolina	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	42	....	42
South Carolina	....	1	1	....	1	1	....	1	1	....	1	1	....	1	1	....	1	1	2	1	3	98	4	102
Georgia	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	7	....	7	43	....	43
Alabama	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	3	35	....	35
Mississippi	1	....	1	1	....	1	1	....	1	1	....	1	1	....	1	1	....	1	2	....	2	20	....	20
Louisiana	....	....	....	....	....	....	....	....	....	1	....	1	1	....	1	1	....	1	4	....	4	36	2	38
Ohio	1	....	1	1	....	1	....	....	....	....	....	....	....	....	....	3	....	3	16	1	17	107	15	122
Kentucky	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	1	....	1	3	....	3	38	4	42
Tennessee	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	29	5	34
Indiana	....	....	....	....	....	....	1	....	1	1	....	1	1	....	1	3	....	3	6	....	6	59	....	59
Illinois	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	1	6	56	13	69
Missouri	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6	....	6	39	1	40
Arkansas	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	2	5	....	5
Michigan	....	....	....	1	....	1	1	....	1	2	....	2	2	....	2	3	....	3	2	....	2	29	6	35
Florida	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	38	....	38
Texas	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14	1	15
Iowa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	2	10	4	14
Wisconsin	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	....	....	....	7	....	7	26	4	30
California	2	1	3	....	1	1	....	1	1	....	1	1	1	1	2	....	1	1	3	1	4	19	3	22
Minnesota	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	2	....	2	7	2	9
Oregon	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	2	7
Washington Territory	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	3
Nebraska Territory	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	1	....	1
Kansas Territory	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	2
New Mexico Territory	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Utah Territory	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Coast Survey office & assistants	6	....	6	5	....	5	15	....	15	7	....	7	11	....	11	11	....	11	39	....	39	176	....	176
Officers of the army	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	172	....	172
Members of Congress	7	....	7	11	....	11	17	....	17	16	....	16	16	....	16	27	....	27	52	....	52	134	....	134
Officers of the navy	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	93	....	93
Executive departments	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	38	....	38
Revenue bureau	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	....	20
National observatory	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	30	....	30
Light-house Board	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	....	20
Newspapers	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	197	....	197
Foreign	3	....	3	3	....	3	4	....	4	3	....	3	3	....	3	6	....	6	634	....	634	253	....	253
Total	31	3	34	37	6	43	71	7	78	64	7	71	81	6	87	127	7	134	996	8	1,004	3,448	178	3,626

Aggregate **5,077**

Statement of Coast Survey maps, charts, and sketches printed during the year.

SECTION I.

	No. of impressions.
Sketch A	30
Sketch A *bis*.	30
Mouth of Kennebec river	20
Portland harbor	100
Eggemoggin reach	25
Sow and Pigs reef	50
Provincetown harbor	210
Harbors of Ipswich and Annisquam	163
York River harbor	100
Boston harbor, scale $\frac{1}{175000}$	100
Boston harbor, scale $\frac{1}{40000}$	264
Harbor of Wood's Hole	202
Sea-coast chart No. 3	20
Plymouth harbor	225
Sea-coast chart from Plymouth to Saughkonnet	217
Stellwagen's bank	60
Newburyport harbor	100
Harbors of Holmes's Hole and Tarpaulin Cove	25

SECTION II.

Hudson river triangulation	60
Mouth of Connecticut river	205
General chart of the coast from Gay Head to Cape Henlopen	20
Sea-coast chart No. 7	10
Hell Gate	232
Harbor of New Haven	227
Long Island sound—eastern sheet	16
Long Island sound—middle sheet	16
Long Island sound—western sheet	16
New York bay and harbor and the environs, sheet No. 1	45
New York bay and harbor and the environs, sheet No. 2	45
New York bay and harbor and the environs, sheet No. 3	45
New York bay and harbor and the environs, sheet No. 4	45
New York bay and harbor and the environs, sheet No. 5	45
New York bay and harbor and the environs, sheet No. 6	45
Romer shoal and Flynn's knoll	65
Captain's island, East and West	200
Hempstead harbor	20

SECTION III.

Sketch C	30
Chesapeake bay, sheet No. 1	6
Wachapreague, Machipongo, and Metomkin inlets	50
Patapsco river	208
Mouth of Chester river	100
Delaware and Chesapeake bays	105
Sea-coast of Virginia and entrance to Chesapeake bay	59

	No. of impressions.
Delaware bay and river, sheet No. 1	220
Delaware bay and river, sheet No. 2	195
Delaware bay and river, sheet No. 3	201
Sea-coast of Delaware, Maryland, and part of Virginia	25
Section IV.	
Sketch D	30
Cape Fear River entrances	50
Cape Fear river, from Federal Point to Wilmington	265
Albemarle sound	175
Frying Pan shoals	77
Beaufort harbor	100
Section V.	
Sketch E, and sub-sketches	90
Charleston harbor	122
Romerly marshes	67
St. Simon's sound and Brunswick harbor	6
Bull's bay	20
Section VI.	
Sketch F	60
Florida reefs	20
Section VII.	
Sketch G	30
St. George's sound	45
Pensacola harbor	121
Section VIII.	
Sketch H	30
Biloxi bay	150
Mobile bay	91
Entrance to Mobile bay	107
Section IX.	
Coast of Texas, from Galveston bay to San Luis Pass	20
Coast of Texas, from San Luis Pass to the head of Matagorda bay	10
Section X.	
Sketch J—lower sheet	30
Sketch J—middle sheet	30
Humboldt bay	20
Santa Cruz and Año Nuevo	116
San Diego bay	126
Mare Island straits	175
Entrance to San Francisco bay	109
Reconnaissance of the western coast of the United States from San Diego to San Francisco	25
Reconnaissance of the western coast of the United States from San Francisco to Umpqua river	25
Prisoner's, Cuyler's, and San Clemente harbors	60
Crescent City harbor	30
San Pedro harbor	20

SECTION XI.

	No. of impressions.
Sketch K	30
Reconnaissance of the western coast of the United States from Umpquat river to the boundary	25
Canal de Haro	72
Washington sound	233
Semi-ah-moo bay	100
Cape Flattery and Nèe-ah harbor	150
Bellingham bay	43
Port Ludlow	65
Port Gamble	205
MISCELLANEOUS.	
Diagrams showing limits of $\frac{1}{80000}$ finished maps	60
Proofs from finished and unfinished plates	1,852
Scale of letters	50
Scale of shades	50
Chart of the Pleiades	268
Diagrams of observations at Girard College	55
Gulf Stream explorations	20
Diagrams for Tidal Division	940
Project limits, $\frac{1}{400000}$	20
Sketch of progress	562
Magnetic declination	100
Magnetic dip and horizontal intensity	100
Map of the world, on a polyconic development of the sphere	80
Contact slide apparatus	50
Mitchell's tide-gauge	50
Trenchard's tide-gauge	50
Approximate co-tidal lines, Atlantic coast	50
Diagrams of wind—Western Coast	54
Map of Washington	208
Saxton's tide-gauge	50
Deep-sea soundings, Gulf of Mexico	34
Improved deep-sea sounding apparatus	30
Mitchell's sub-current apparatus	62
Circular protractors	12
Total	12,679

APPENDIX No. 20.

Reports of Assistant H. L. Whiting, on topographical contour, hydrographic details, and reduction, on photography, and on the scale of shades suitable for complete maps.

COAST SURVEY OFFICE, *April* 10, 1860.

DEAR SIR: In continuation of the subject of generalizing details in making reduction for charts on the scale of $\frac{1}{80000}$ and smaller, opened in my letter of January 6, the following additional particulars are communicated for the guidance of the office.

GENERALIZATION OF CONTOUR AND OTHER NATURAL FEATURES FOR REDUCTION TO $\frac{1}{80000}$.

Contour.—The feature of contour is in itself so varied a subject that it is impracticable to give definite rules which will cover all cases. The draughtsman or reducer must have some latitude, and exercise judgment and discretion in the modification and generalization he applies to the matter before him. Some rules can be observed, however, which will lead to system in the process of reduction and uniformity in the results.

In reducing contour the peculiar formation of the country should be carefully studied, and the general character of the mountains, hills, or undulations, made the basis of generalization. Main ranges and general forms of hills should be preserved, while smaller details of broken and irregular contour, which are overcome by the general features of the hill or range, may be modified or omitted, according to their conspicuousness and extent, and the incapacity of the scale to express them clearly.

In cases of particularly broken and irregular contour, such as Cape Ann, Cape Cod, and parts of the coast of Maine, the reduction and generalization must be made more in reference to the size and natural conspicuousness of individual features, at the same time studying the general formation and *rising* of the land from the shore. Certain general forms and features can sometimes be traced even in the most broken and apparently irregular country; and as these would be all that could be clearly distinguished in a distant view of the coast, they should have a corresponding conspicuousness and expression on our coast charts, which, on the smaller scales, are intended to represent, as it were, such a diminished or distant view.

Where a low, undulating country is to be reduced, with slopes varying from one to ten degrees, and elevations from twenty to three hundred feet, the very nature of the contour will admit of the full representation of such slopes and forms, and, therefore, the generalization should be made with the full number of 20 feet curves. The rule being to generalize minor features and irregularities of not over one hundred metres in extent, or of from five to fifteen feet in height.

Where slopes from five to twenty degrees predominate with heights from 50 to 500 feet, the generalization may be made with 40 feet curves, modifying minor details of from 100 to 150 metres in extent, with heights from 10 to 30 feet.

In sections of still bolder and larger features of contour, as on our western coast, where slopes from ten to forty-five degrees occur, with elevations of 1,000 and 2,000 feet, the generalization may be made with 100 feet curves, and minor details of from 100 to 200 metres in extent, and from 20 to 50 feet in height may be modified or omitted.

In all cases where 40 and 100 feet curves are used in reducing and generalizing contour, when features of characteristic importance occur *above*, *between*, or *below* these curves, such as summits, spurs, and ridges, and the sloping bases of hills, &c., auxiliary curves shall be used as a guide to the engraver and in hachuring.

As different features of contour on the same map, or in the same locality, may require the use af all these curves of generalization, a distinct sign shall be used for each curve, viz:

For 20 feet curves, a full line.

For 40 feet curves, a dashed line.*

For 100 feet curves, a dashed and dotted line.

For auxiliary curves, a dotted line.

Important summits should be noted by figures.

A few experiments with different subjects carefully treated would be the best practical illustration of these rules, and the best guide in their future application.

*The dashes used as a sign for 40 feet curves shall be longer than those used as the sign for fences or secondary roads, so as not to confuse with these signs.

Salt marsh.—Next to contour, salt marsh is perhaps the most important characteristic and unalterable natural feature of our coast topography.

In reducing large tracts of salt marsh, the general character and condition of the marsh and of the surrounding country should be considered. If it is a broken, soft marsh, full of fibrous creeks, like that in San Francisco bay, its generalization would require different treatment in reduction from the firm and uniform marshes of Delaware bay. In one there is a vast number of small creeks breaking up the entire mass of the marsh with comparatively few leading to landings, or fast land. In the other case each creek almost leads to some pond or other source, or is the outlet of some fresh water stream from the back country. The same size and character of creek, therefore, has a different significance, according to the kind of marsh through which it runs, and the importance it may have as a peculiar feature.

In generalizing details in salt marsh the following rules may be observed, viz:

All main creeks which are 10 metres wide, or more, and which can be distinctly shown by double lines, shall be represented as given on the field-maps. Small fibrous creeks branching from these main creeks, and not leading to any important locality in or through the marsh, may be omitted. Small ponds and water holes, if not over 100 or 150 metres in extent, may be omitted. Small hammocks of fast land, near the general outline of fast land at the head of coves, &c., and such as are not conspicuous landmarks, or important for landings, &c., may be omitted when of less size than 100 or 150 metres. Minor irregularities of 100 or 150 metres in the outline of fast land surrounding tracks of salt marsh may be generalized to uniform sweeps and lines. Small detached patches of salt marsh of 100 or 158 metres in extent, within the general limits of fast land, may be omitted.

The limits of fast land or sand beach, bordering salt marshes, should be shaded by grassing or dotting, to indicate the general rising of such land from the level of the marsh; this will define the outline distinctly, and give a good contrast and effect to the different features.

Sand beaches and sand hills.—The outside line of sand beaches forms a large proportion of the main sea-coast, and will come under the rule for reducing and generalizing shore-line given under that head.

The inside line of beaches bordering on ponds, marsh, or fast land, is generally more irregular than the outside line, and may be modified and generalized in the same way as the outline of marsh and fast land by blending small irregularities of 100 or 150 metres into general sweeps and lines.

Sand hills on many ocean beaches are a conspicuous feature, and often important landmarks. The general formation and condition of these hills should be carefully studied, and the reduction made to express the general characteristic effect. As a general rule, the outside range of sand hills and bluffs should be reduced as closely as the scale will admit, particularly on southern beaches where there is no high land showing behind them. Irregular masses of sand knolls, &c., back of the general sea-line of hills or bluffs, can be generalized and blended as their condition and form may require. Individual knolls of 100 or 150 metres in extent, and not more than 10 feet high, may be omitted at discretion. On beaches where few sand hills occur, those that do exist should be represented even if quite small.

Single trees and clumps of trees growing on ocean beaches should be represented in the reductions, particularly where the beach is far from the main land, or where the country is not generally wooded. Where a larger extent of woods occurs the general outline should be well defined. If it is open and irregular in its growth, small patches of trees and open spaces of 100 or 150 metres in extent may be generalized and blended in the general mass of wood.

Woods.—The natural growth of woods forms a distinguishing and conspicuous feature in many sections of our sea-coast, and their importance as a topographical feature may be classed with their conspicuousness. In the northern sections, where they have been partially cleared off, and where they are scattered unequally over different kinds of contour, they become

a secondary feature. In some of the southern sections where they form the general background of the coast they form a first class feature; and, again, as on parts of the coast of Texas, their entire absence becomes a peculiar characteristic of the coast. In the first case, small patches of woods of 100 or 150 metres in extent, and even larger patches of irregular and open growth, are often obscured by more conspicuous contour, and may be omitted at discretion. Irregularities in the outline of large masses of woods, both in hilly country and in the middle and southern sections, may be generalized in the manner of other outlines and to the same extent, 100 or 150 metres.

Small detached patches and open spaces of 100 or 150 metres in extent, where they occur among larger masses, may be omitted or filled up, respectively, at discretion.

In sections of the coast where few trees exist, and on islands and beaches remote from the main shore, omissions should not be made, but small clumps and even single trees should generally be represented.

Fresh marsh.—On our sea-coast fresh marsh is not a general or extensive feature, and not naturally conspicuous. Small detached pieces of fresh marsh, from 100 to 150 metres in extent, when they occur among broken and wooded hills, may generally be omitted as an inexpressive feature. Where they indicate hollows or stream beds they should be expressed, within the capacity of the scale, say to 100 metres in extent. The margins of ponds and the sources of streams, where they occur in open and cultivated land, should be indicated within the capacity of the scale, to show distinctly, say, from 50 to 100 metres.

Shore-line.—The limit of land and water is the most striking and important outline which exists in nature, and it should be the strongest and most conspicuous line of boundary between natural features represented upon a map. To give proper effect to this feature in publications, the actual shore-line should be made strong and conspicuous, and represented by a full black line of not less than three metres thick, and may, in some characters of shore, be made five metres thick. Besides this, which we may term heavy line, the immediately adjoining topography should be distinctly and strongly represented by its proper sign; and if it be of sand, marsh, level upland, rising hill-sides, or rocks, the representation should be slightly stronger than that used for the same sign further back from the shore. This will give a more striking contrast to the limits of the land and water, and will show the detail outline of bays, coves, points, islands, &c., in strong relief, which is important. While the strength of the shore-line and tone of the adjoining topography are increased, the low water sanding, and one, two, and three fathom curve sounding, where given, should be made as light and open as the sign will bear. This will still further increase the contrast between the land and water, and be a marked improvement in the general and detailed effect of the maps of the Coast Survey, which unite the properties of both maps and charts, and particularly require distinctness and naturalness in each of these characteristics. The example prepared as a sign for "wet sanding" will show the degree of tone and effect to be produced in representing this feature.

In reducing and generalizing the detailed irregularities of shore-line, a careful study should be made of the general character and formation of the adjoining topography, and not only the mere water line be generalized, but the character and formation of the coast blended in the general representation.

In the shore-line of a broken and rocky coast, like parts of Maine, Cape Ann, &c., irregularities of rocks and ledges, which are evidently of the same character as the general coast line, may be generalized to a greater degree than irregularities of the same dimensions, but of different nature. Thus the small, smooth coves, which sometimes occur along the shores of a rocky coast, have a different topographical character from the general formation, and should be noticed with particularity. In the same sense a point or ledge of rocks, breaking out from a generally smooth shore-line, should be more minutely represented than the same point need be if occurring with a mass or continuation of similar rocky points and ledges along a naturally

rough and broken coast. As a general rule, therefore, the irregularities of shore-line on a coast of uniform character may be modified and generalized to a somewhat greater degree than where the character is varied, and detailed irregularities of from 30 to 50 metres in extent be blended in the general representation.

This will apply particularly to the rocky shore-line of New England, to hard marsh shores, such as occur in bays and sounds, and to coral banks, like the shores of the Florida keys. The shore-line of sand beaches and of bays and rivers of earth formation are generally more sweeping and uniform and can be reduced with slight modifications; where irregularities do exist, they are more apt to be in the banks, bluffs, and ravines immediately bordering the shore than in the actual water-line, and should be treated more as features of contour than of shore-line, and generalized as their character and importance may require. Where small banks and bluffs, with gullies and ravines, do occur, they are generally in a shore either level or slightly undulating, and are features not generally involved with other details, likely to obscure or confuse them; and as they are closely connected with the actual shore-line, the generalization should not be as great as may be made with the same class of features further inland. A limit of 50 metres in extent should include all the ordinary details to be omitted or generalized.

The shore-line of islands comes under the same rule as applied to main shore-line. In cases of small islands, single rocks, &c., which occur in localities of hydrographic importance, they should be strongly and distinctly represented, and if quite small they should be exaggerated to the size of 25 metres, and no single rock near a channel way, or so distant from shore as to be dangerous to navigation, should be represented less than this size. Where a number of rocks are clustered together, making the mass conspicuous, the individual rocks may be indicated by a smaller sign if necessary.

Low water.—Low water, both to the field topographer and hydrographer, and in the office operations of drawing and reducing, is the most uncertain and difficult to determine and express of any natural feature of the survey.

The question of the determination of this feature in the field at once presents a practical and physical difficulty of serious importance. The means and methods of the topographic and hydrographic work have conditions both in favor and against assigning the determination of it exclusively to either of these departments of the survey.

There are circumstances and cases where the topographical survey could not embrace all features of low water unless at great disadvantage and expense, and even then imperfectly and inconsistenly with hydrographic results. On the other hand, the hydrography could not develop all the irregularities of low water by the ordinary process of field-work. In bays, coves, rivers, &c., where the character of the shore is irregular, the condition of the shore at low water generally corresponds to that of high water, and the points, islands, banks, &c., of such shores, afford facilities for the topography to determine the low-water line with rapidity and accuracy, with all minor details commanded and determined. The same degree of detail, however, could not be obtained by the usual hydrographic process of work.

Shoals off-shore, in the middle of large sounds and bays and extensive flats, either connected or unconnected with the main shore, can be determined more favorably and economically by the hydrography. They come within the full scope of that work, and can generally be commanded by sounding lines and angles in a satisfactory manner. The position being remote from shore, often of soft and undefined substance, impracticable for occupied stations, makes the determination by the topographical parties difficult and objectionable.

A question of accuracy is involved in this matter beyond the mere process of the survey. The hydrographic results are based on a condition of tide not naturally visible, being "*mean low water;*" where the limits of shoals and middle grounds and extensive flats are reduced to the same plane, the results coincide with the soundings and the development of the bottom,

which is important in relation to navigation. In the irregularities or extent of low water nearer the land this condition is not so essential, as the shore is more cautiously approached by vessels, and therefore less dangerous in navigation.

In consideration of these facts, the actual survey of low water may be advantageously assigned, in division, to both the topographical and hydrographic parties, under the following general rules:

1. All low-water limits, extending from the shores of bays, sounds, rivers, &c., and around islands, shall be determined, in all the necessary detail, by the topographical parties, to a distance averaging one-quarter of a mile (400 metres) from shore, the survey to be made as nearly at medium tides as practicable and consistent with the general progress of the work.

2. In cases of off-shore shoals, middle grounds, flats, &c., and all low-water lines extending beyond the prescribed limits of the topographical survey, the determinations shall be made by the hydrographic parties, and considered as their especial duty.

3. Where cases of peculiar character and condition occur, making it advisable to modify this rule, full official authority shall be had to deviate from it, with a distinct agreement and understanding between the field, topographical, and hydrographic parties in regard to the case in question.

4. In addition to this assignment of the field-work, each party shall include as much of the low-water determination, beyond the limits prescribed as its particular duty, as can be commanded and determined in the regular operations of each party, not interfering with proper progress. This will serve as a test to both operations, and aid in adjusting differences which may occur.

This reference to field-work is made as a preface and guide to the office adjustment of work already done, and as a basis for the rules and reasons for adopting or relying upon one standard of party results rather than another. The same argument holds good in favor of inclining to the hydrographic results for off-shore low water, and the topographical results for low water near the main land, in the office as in the field.

Frequent instances of disagreement in results occur under circumstances of doubt as to whether the differences are errors of survey or the result of changes which have occurred between the dates of the separate surveys. As a general rule, in adjusting such cases, the natural formation and character of the coast shall be considered; and if it is one liable to change, and the error is not so great as to require revision of field-work, and the different surveys are equally reliable, the results of the *last survey made* shall be taken. If this does not cover the case, and there are no data by which to determine changes or errors in either survey, the results *conforming most naturally to the surrounding topographical and hydrographic details* shall be adopted. If doubt still exists, the subject shall be referred to the Superintendent to order a resurvey.

Returning to the consideration of the office reductions and generalization of low water, I would remark:

1. The sign for low water shall be that uniformly used for sand, viz: dotted work, and in the style called "*irregular sanding.*" The arguments in favor of this sign and of discarding the sign of mud are, first, the greater proportion of sand in low water formation to any other material; second, the uncertainty as to whether the shoal is mud or sand, being in most cases remote from shore, and only observed upon from distant stations; third, the uniformity and consistency of this sign with that used for the one, two, and three-fathom shoals, which is sand, even where written indication is given of different character of bottom, as sticky, soft, &c.; fourth, the advantage of a uniform and given sign for a uniform feature.

2. The style and tone of this sanding shall be a medium between the high water and "wet sanding," making it conform more to the tone of the latter, in order, as stated under an other head, to give contrast and relief to the shore-line, or limit between land and water. The out-

side limits of shoals left dry at low water, being the low water line, shall be a dotted line, but slightly closer and more distinct than the line of the one, two, and three-fathom shoals. The main level of low water flats and shoals shall be as open as the sign and scale will bear.

3. Where features of peculiar character occur in the body of low water shoals and flats, or where such shoals are composed entirely of materials other than sand or mud, the following signs shall be used, viz:

Ledges of solid or broken rock: imitation of rock, showing strata, &c.

Loose stones, boulders, &c.: imitation of large and small stones, &c.

Oyster beds and shell banks: imitation of shells.

Coral reef: imitation of coral.

4. In generalizing the outline of low water freedom may be taken with small irregularities as in other outlines, and modifications made where occasion demands to a greater degree than with high water—details of 100 metres in extent being blended and omitted in expressing general lines and curves at discretion. Where figures of soundings occur along the outline of low water, showing the depth of small coves or holes, the feature shall be exaggerated, if necessary, so as always to show the sounding figures clearly and distinctly within the space indicated.

In generalizing the outline of rocks, ledges of stones, coral reefs, &c., small irregularities may be modified as above; and small detached features of 50 and 75 metres in extent be omitted where they come *within* the general limits of the shoal.

II. Hydrographic Reductions.

In treating the subject of hydrographic reductions the following views are presented for consideration:

In adopting a system of rules and signs the question of minuteness and complexity should be borne in mind; the reductions and generalizations made to conform to the capacity of the scale, and the signs adopted, both for natural features and individual objects, should be simple, distinct, and characteristic, and sufficiently descriptive to give proper information, and guard against confusion and mistakes.

While the main question under consideration is to free the charts from an excess of detail, it may still be necessary to add certain details where important features require them; and the advantage of showing the *channel of deepest water* by some proper and conspicuous sign is one of much interest.

A uniform system of lettering, in the size and character of letters used, will tend to a more ready understanding of the maps. The size and style of figures for soundings is a question of mechanical practicability which is already undergoing some tests in the engraving process. Experiments are being made with punches, which, if successful, will tend to uniform and satisfactory results. The abbreviations for the characters of bottom are already well established and sufficiently good.

The above remarks are made on the present condition of the work as a preface to the general remarks which follow, and as pointing to the reasons and objects for change and improvement, for which I would respectfully recommend the following rules and signs:

1. The actual shore-line, as the most important and conspicuous limit of distinct natural features, should be the strongest line used as a corresponding conventional sign. This has been established under another head, and is to be a full black line, from three to five metres thick, according to the kind of shore to be represented.

2. Low water, as an extensive feature, and its outside limits, as the "low-water line," are to be represented according to the rule and sign established by dotted work. The low-water line to be reduced and generalized in its details, conforming to soundings and hydrographic results, as circumstances may require, under the rules given.

3. The sign and style for representing the one, two, and three-fathom shoals shall be uniformly of dotted work, in the manner termed "*irregular sanding.*" The limit of each shoal being the one, two, and three-fathom "curve" shall be a dotted line, from which a narrow border of shading by closer dotted work shall be made, blending with the more open tone of main surface of the shoal, which shall be of a uniform and even tint.

These dotted lines, and the tone of the different shoals, shall be made gradually more light and open as they increase in depth.

In reducing and generalizing these features from the original hydrographic sheets small irregularities may be modified as in other features of the work, blending small points and coves into such general sweeps and lines as can be clearly expressed on the reduced scale.

A general rule shall govern the reduction of these details where they are connected with figures of sounding, which is to make all points and spots and all coves and holes sufficiently large to show the outline of such details separate and distinct from the sounding figures.

The style, tone, degree of closeness, or openness of the sign for this sanding, shall be in exact accordance with the sample given.

4. In preliminary sketches, or in charts where the fathom shoals are not sanded, the fathom "curves" shall be indicated by dotted lines with the sign for the denomination of each curve given as now used, viz:

Single dots for one-fathom curves.

Double dots for two-fathom curves.

Triple dots for three-fathom curves.

The number of dots and the distance between each group shall be so separated and distinct as to make the sign for each curve plainly distinguishable. Where small features and irregularities in these curves occur the dotting may be brought closer together at the particular point in question if it is necessary to do so in order to show the detail curve of the line, &c. The same rule with regard to surrounding the soundings; figures shall be applied, as in dotted work, so as to avoid all confusion and indistinctness of details and figures.

These curves may be reduced according to the rule established for the sanded shoals, generalizing minor irregularities of 100 metres in extent at discretion.

5. Rocks "awash" shall be shown by the usual sign of a black star; the length of the crossing lines where a single rock is indicated shall be fifty metres; where a cluster of rocks occur, they may be shown less than this size if desirable, but not less than thirty metres.

6. Sunken rocks shall be shown by the usual sign of a black cross; the length of the crossing lines shall be fifty metres for single rocks, and from this size to thirty metres for clusters of rocks at discretion.

7. The size and style of sounding figures shall be according to the samples given, and all the figures, with their fractions of the same denomination, shall be of equal and uniform height.

Fractions of fathoms of one-fourth, one-half, and three-fourths may be used where required, but all fractions of feet shall be omitted. Three sizes of figures only shall be used, the largest for off-shore and deep soundings; the second or medium size, for sounds, bays, and waters where the details do not require very close work; the smallest size in narrow channels and circumscribed localities, where the figures require to be numerous and close, and not to be generally used unless the work requires it.

The following signs shall be used for the artificial details connected with hydrographic matter:

Revolving light: white spot, fifty metres, rays fifty metres.

Fixed light: black spot, fifty metres, rays fifty metres.

Lighted beacon: spot fifty metres, rays fifty metres.

Light-ship: ship 100 metres, rays 100 metres.

Bell-boat: boat 100 metres, mast 100 metres.

Dark beacon: sides of triangle fifty metres.
Spindle: spot fifty metres, stake seventy-five metres.
Can buoy: diameter seventy-five metres.
Nun buoy: diameter seventy-five metres.
Spar buoy: length 100 metres.

The question of notes, tables, references, &c., in text, which accompany our charts, is one depending so much on local peculiarities and conditions that no precise rule can be given in regard to it. In arranging and preparing these matters as items of information, I should recommend having as much put upon the face of the chart as practicable, such as signs, sailing courses, ranges, &c., represented and drawn rather than described.

In developing and indicating the navigability of bays, harbors, rivers, &c., uniformly and consistently with the depth of water which can be carried into such waters over outer bars and through outer channels, I would recommend the following general rules, which in some cases will free the map from considerable detail, and at the same time add to its clearness and effect:

1. In maps of bays, harbors, &c., where the depth of water at the *entrance is more than one fathom and less than two fathoms*, the "sanding" of the shoals on such a map shall be made to one fathom only.

2. Where the entrance has a depth of *two fathoms and less than three*, the sanding shall be made for one and two-fathom shoals only.

3. Where the entrance has a depth of *three fathoms* and *over*, the sanding shall include the one, two, and three-fathom shoals.

4. Beyond this depth, and for all entrances between *three* and *five fathoms*, the channel of *deepest water* shall be indicated by a full line, with the exact depth of such channel *in feet* written along this line near the bar or entrance of the bay or harbor in question.

5. Where a bar or spit makes off or produces breakers, &c., near the entrance of harbors of shoal entrance, they may be indicated by dotted lines if of greater depth than the main channel. Thus, a one-fathom harbor with the one-fathom shoals sanded may have a two or three-fathom outside bar indicated by dotted lines, (as by rule.)

We have thus at a glance the capacity of each harbor indicated, and while the deeper harbors and channels are defined and classified, as San Francisco, Portland, Newport, New York, Norfolk, &c., the harbors of lesser capacity are not closed, and the details of bottom, currents, buoys, figures, &c., felt much more clearly and distinctly than when expressed over sanded and darkened ground.

III. Reductions by Photography.

The reduction by photography of the original field-sheets of the Coast Survey to the smaller publication scales has proved, so far, successful, and is so much more rapid and accurate in its results than the best methods of hand reduction heretofore used that it will be considered as the basis of the rules and process of reduction to be adopted, and which I herewith present for your approval.

Some general directions may be given establishing system and uniformity in the office operations which will tend to facilitate the preparation of work, and insure accuracy in final results.

In taking up the project of a coast chart, after being thoroughly considered and adopted, the following rules should be observed:

1. The examination of field-work and the topographical and hydrographic material for the map. Investigation as to when the surveys were made; who by; if they have been verified in the field; the date of this verification; if the section of coast involved is liable to change, &c., with the question of examination or resurvey of changes, if already made or necessary to be made.

2. Inquiries instituted to collect all collateral information, such as names, &c., which may be

wanting; application to Light-house Board for light-houses, buoys, &c., and all matters referring to them. Application to War Department for signs for forts, &c., and other matter referable to it.

3. Consideration of title for maps, names of field assistants, &c.; notes, tables, &c. A manuscript should be carefully made of title, notes, tables, &c., to be a *fac simile* of that to be engraved, and adjustments, alterations, &c., made upon it, perfecting *all its arrangement* before the engraving of title and notes is commenced.

4. After examining the material to be employed, the projections, points, joining of sheets, &c., should be tested, and all errors of shrinkage and disagreements not referable to field-work should be reconciled and corrected.

5. Before tracing and generalizing the field-sheets thus prepared, the outlines of detail should be examined by an experienced draughtsman, and all cases of faded or indistinct work carefully gone over, and all lines and objects to be traced made so distinct that there will be no liability of error or omission in discerning them through the vellum or tracing paper used.

6. An accurate projection, corresponding to the projection of the field-sheet to be traced, should then be made on vellum, and the details of the field-sheet traced in outline, equalizing and generalizing errors of shrinkage, &c., minute by minute, on the new projection. Joinings of different sheets which may have irregular shrinkage or other minor disagreements should be adjusted and made to coincide on this vellum projection.

7. In tracing the details from the original field-sheets the generalization should be made, for which rules have been given for each particular feature, shore-line, roads, enlarging them if necessary to the width required as the sign, omitting private roads, &c. Shading of town and village blocks and streets, giving the proper sign for single houses, out-houses, &c.; omitting unimportant buildings, &c., fences; omitting lots less than 100 metres square; marsh, with the accompanying details of creeks, ponds, hammocks, &c., generalized according to the rules given. Woods, fresh marsh, &c., generalized according to the rules given; contour generalized according to the rule given, with the 20, 40, and 100 feet curves drawn according to the sign given for each, &c.

8. The style of this tracing should be adapted to the purpose of photographing, for which it is especially intended, giving proper distinctness and effect to the reduced photograph. The traced lines should be made in pure black ink, and all outlines, as shore-line, roads, &c., should be stronger and heavier than contour lines or lines of secondary features.

9. This tracing should be carefully examined and compared with the original sheets traced, and all omissions and errors corrected; the number of the sheet and the date of the tracing written in sufficiently large figures and letters on the tracing to be read distinctly when photographed.

10. Duplicate photographs should then be taken on $\frac{1}{40000}$; one for the purpose of hachuring where the details of contour require it as a guide for engraving, and the other for reference to the contour lines in verifying the hachuring made.

11. Duplicate photographs should then be made of the same tracing on $\frac{1}{80000}$. One on glass for the engraver for tracing outlines and contour; the other on paper, to be colored and worked up by the draughtsman as the guide and standard for signs and detailed representations.

12. The working up of the photographed reduction must depend on the character and detail of the natural features and the closeness of the work reduced. Rules have been given for all the natural and artificial signs, and a system of colors as substitutes for the details of signs for all features in masses. There may be cases, however, of complex and varied details where the simple legend of color will not answer as a full guide to the engraver; in such cases the signs, hachuring, and other details to be expressed must be worked up fully and completely by pen

work, in the style and according to the precise rules given for the features and details in question.

13. Having completed the arrangements and operations above specified the work is ready for engraving. This is a process depending for its excellence upon the practical and artistic skill of the engraver; and in this fact has existed the greatest difficulty and want of uniformity in the former publications of the survey. But it is expected that the rules, signs, and directions which have been provided for every feature and department of this work will insure uniform and certain results. While the maps are relieved from confusing and minute details, such features only are required to be represented as come within the full capacity of the scale, and with the sign given for each feature when followed in outline and in tone; in accordance with the sample and rule provided a series of maps should be produced in harmony with each other, and possessing the uniform characteristics of the country and of the survey.

14. All provisional matters involved in the publications should be prepared for as early as practicable. For instance, the position and character of forts, light-houses, &c., should be given to the engraver with the first of his work outlines, in order that he may accommodate the detail of his work to the sign which is to be represented.

15. To facilitate the engraving operations and insure uniformity in details, punches and dies will be made for small signs where practicable, such as houses, light-houses, buoys, sounding figures, sunken rocks, &c. Gravers for lines of certain and established sizes, both for outline work and for hachuring, can also be made.

Thus different operators of varied ability, skill, and taste can work independently of each other, and yet their work when brought together will not be strikingly dissimilar, except in point of execution.

16. In no instance is a reducer, draughtsman, or engraver to depart from the rules and signs prescribed for the representation of the work unless by special official authority, and with full understanding of the necessity and advantage of such deviation from rule.

IV. Scale of Shades.

I present herewith a report on the scale of shades adapted to the hachuring of hill contours as determined by the operations of the Coast Survey, and required for their representation on the published maps.

This subject has been ably and elaborately treated in former discussions by Lieut. A. A. Humphreys and Assistant W. M. C. Fairfax, and the merits and demerits, both in general and detail effect, of the different systems of shade and hachuring fully considered and argued. I will not, therefore, go over this ground again in presenting the results of the investigation of this subject, which you directed me to make.

Practical difficulties and objections were found to exist in all of the former systems of shade used; some in the mechanical process of drawing and engraving, others in the effect produced.

To develop the capabilities of the different scales of shades a careful practical test has been made of those deemed most worthy of trial by applying them in hachuring a subject of natural contour which had been closely surveyed—involving varied and extreme slopes—the result has been quite satisfactory, and has led to the construction of a scale of shades combining the merits of the different scales tested, with some modifications and additions, which is herewith presented for your approval.

It is proper to state here the reasons why neither of the already existing scales were adopted, and also to give the basis and reasons in favor of the scale proposed.

1. Lehman's scale, as reported by Lieut. (now Capt.) Humphreys and Mr. Fairfax, and proved by the tests now made, has not sufficient range, and any other conventional sign for *rocks*, &c., above 45°, (which, its advocates contend, is a recognized part of his system,) is

deemed inferior to hachuring where hills of rock formation are unbroken in surface, which is common in nature.

2. Capt. Humphreys's scale has strength and range, without a sufficient *variety*, and lacks contrast between important slopes.

3. Mr. Fairfax's scale is a combination of others, and has been carefully studied and constructed. The subject was taken up by him for the same reason which led to the present investigation, viz: the inadequateness of other scales. The system and philosophy of his scale are excellent, and have been taken as the basis of the new scale proposed; but in the extreme ranges, both of the upper and lower slopes, he has carried his lines and spaces to an impracticable degree of fineness.

The new scale proposed is based upon the strong and effective line of Lehman, from 5° to 25°, its best section, and from 25° to 40° it follows the line or curve of natural sines. This gives at 5° a proportion of one part of black to eight of white, and at 40° four parts of black to one of white. Within this range the scale has been found to answer all practical demands in representing natural contour, and is considered the best gradation of light and shade which experiment could develop. Beyond these well known and mathematical bases the scale is extended in the higher range to 75°, and in the lower range to 1°. This has been done by continuing the same strength of line, as at 5°, with an increase of 25 per cent. of white for each degree from 4° to 1°, inclusive, which gives a distinct yet pleasing contrast between these important slopes. In the higher range the unit of *black* is increased 25 per cent. for the first 5°, and 25 per cent. each for the next three divisions of 10°, leaving the last 15° of slope from 75° to 90° in full black.

This construction and arrangement has been the result of careful and labored practical experiment, both in drawing and engraving, and it is believed that the scale in its whole range will be found practicable in execution and graphic in effect.

There is nothing original in this scale, and no merit is claimed for it other than in the experiments which led to its adoption; they have been the same which I have endeavored to apply to all the subjects under examination and revision during my winter's duty, and based upon the principle that one *fact* is worth many metaphysical opinions and theories.

I have had great assistance from Mr. E. Hergesheimer throughout the whole of this investigation, and aided by his experience, judgment, and artistic skill. Mr. McCoy has also devoted his attention to the subject, and his practical application of the new scale to the engraved specimen of a portion of Cape Ann has been one of the most valuable and satisfactory auxiliaries in our operations.

I append a report of Mr. Hergesheimer's on the details of the scale given, with original and photographed specimens. Also a photographed copy of the experimental drawings, with a copy of the engraved example by Mr. McCoy.

All of which is respectfully submitted.

Very respectfully, yours,

HENRY L. WHITING.

Prof. A. D. Bache, *Supt. U. S. Coast Survey.*

Coast Survey Office, *April* 28, 1850.

Dear Sir: I respectfully report herewith the results of our experiments of applying the different scales of shade to the same hill curves.

1. *Capt. Humphreys's scale* gives so much importance to the range from 0 to 5°, with so little shade in the higher slopes, that too little modulation of shade is left in the range from 5° to 20° to produce the graphic effect demanded by the $\frac{1}{80000}$ Coast Survey maps. This latter range (from 5° to 20°) being the slope most frequently met with on our coast.

2. *Lehman's scale* has much in it that is valuable and desirable to retain. The graduation of shade from 5° to 25° produces the best effect possible, in order to leave sufficient shade before 5° and after 20° for the lower and higher slopes. This is the portion of it which Assistant W. M. C. Fairfax has retained in his valuable scale.

3. The scale based upon the proportions of *natural sines* has also been examined and found to fail in its effect in the most important slopes, (those from 5° to 20°.) It is entirely too light from 0 to 10°, and being of equal proportions of black and white at 30° leaves too little shade from 10° to 30°.

4. *Mr. Fairfax's scale*, which continues with Lehman's from 5° to 25°, and then, by a line parallel to the curve of natural sines, terminates in a horizontal tangent at 60°, is found to produce an effect superior to the others mentioned.

It has been found desirable, however, for the best representation of the higher and lower slopes to modify this scale below 5° and above 40°, leaving the intermediate range unchanged.

The lines of Mr. Fairfax's scale, below 4°, if practicable, are of a fineness very difficult to engrave; again at 40° he exhausts so much of the white (on $\frac{1}{80000}$ scale, unity 100 to the inch) that it is not desirable to attempt to show any less quantity.

The engraver can easily cut a line finer than that given by Mr. Fairfax at 5°, but more than *one* shade below 5° should not be attempted. So in all slopes below 5° it is found best to use the same line and open the hachures as follows:

For 4° with a line $\frac{1}{1100}$ of an inch thick, open 25 per cent.
3° " " " " " 50 "
2° " " " " " 75 "
1° " " " " " 100 "

At 40° the white left between the hachures is $\frac{1}{800}$ of an inch. Less should not be attempted to be shown. Retaining the same white through all slopes above 40°—

At 45° increase the distance between the middle of hachures 25 per cent.
55° " " " " " 50 "
65° " " " " " 75 "
75° " " " " " 100 "

The best distance between the hachures for $\frac{1}{80000}$ scale is found to be 100 to the inch; 75° may be considered the limit, beyond which no scale need be carried, for beyond that not sufficient cosine is left in any natural formations to admit of representation by hachures.

Proportions of *black* and *white* for $\frac{1}{80000}$ scale, unity of 100 to the inch from 5° to 40°, for the other slopes unity as given below:

1°	1 black,	21 white, unity	50	to 1 inch.
2°	1 do.	18 do.	57.1	do.
3°	1 do.	15½ do.	66⅔	do.
4°	1 do.	12¾ do.	80	do.
5°	1 do.	8 do.	100	do.
10°	1 do.	3½ do.	100	do.
15°	1 do.	2 do.	100	do.
20°	4 do.	5 do.	100	do.
25°	5 do.	4 do.	100	do.
30°	3 do.	2 do.	100	do.
35°	7 do.	3 do.	100	do.
40°	4 do.	1 do.	100	do.

45°....$5\frac{1}{4}$ do.	1 white, unity..................	80 to 1 inch.
55°....$6\frac{1}{4}$ do.	1......do..........................	$66\frac{2}{3}$ do.
65°....$7\frac{3}{4}$ do.	1......do..........................	57.1 do.
75°....9 do.	1......do..........................	50 do.

Respectfully, &c., your obedient servant,

E. HERGESHEIMER.

H. L. Whiting, Esq., *Assistant U. S. Coast Survey.*

APPENDIX No. 21.

A resolution providing for the observation of the eclipse of the sun on the 18th day of July, 1860.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Superintendent of the United States Coast Survey be, and he hereby is, authorized and directed to furnish a vessel and provisions for the conveyance to the most suitable point on the eastern coast of this continent for observing the total eclipse of the sun, which will occur on the eighteenth day of July next, of astronomers, not exceeding five in number, and their assistants, to be selected by the said Superintendent of the Coast Survey: *Provided,* That the United States shall not be liable to any other charge on account of the said astronomers and their assistants than their conveyance and provisions, as herein provided, and that they shall furnish their observations for the use of the Coast Survey, without further charge to the government.

Approved June 15, 1860.

Report to the Superintendent of the United States Coast Survey on the expedition to Labrador to observe the total eclipse of July 18, 1860, organized under act of Congress approved June 15, 1860, by Professor Stephen Alexander, LL.D., of the College of New Jersey.

Sir: As astronomer in charge of the expedition sent out under the auspices of the United States Coast Survey, to observe the total eclipse of the sun of July 18, 1860, I beg leave respectfully to report that, in furtherance of the objects of the expedition, the northern extremity of Aulezavik island—very nearly in the path of the central eclipse—was selected as being the position in the vicinity of which our station was to be sought.

We reached the place in question on Friday evening, July 13. On our arrival we found the aspect of the coast to be bold and rugged in the extreme. It in effect presented the appearance of a nearly uninterrupted chain of mountains of awful grandeur. Even the occasional lower elevations among them had the aspect of being enormously difficult of access.

But another and utterly discouraging obstacle had already manifested itself for several miles before we reached the point in question. The mountains of this bold coast were themselves partially covered with snow, and all along the bases of those mountains reposed a quiet, well-defined belt of mist; though the sea further from the shore was free from the same, and the sky superbly clear.

This rendered it at once evident that a position fully open to the ocean was not for one moment to be thought of, but that, on the contrary, if a suitable station were attainable at all in that vicinity, it must be one between which and the ocean the mountains themselves should interpose an effectual barrier to an interference continually to be reproduced under the same law of condensation. With this view, the inlet around the northern portion of the island was

penetrated and examined, with the hope of attaining a station which should at once be free from mist, and at the same time afford (in the judgment of the commander) a safe harbor for the steamer, which would otherwise be much exposed.

This investigation was decided upon, with the approbation of my associates, though it was foreseen that if even successful, we should in all probability find ourselves to the south, but, as we hoped, not much south, of the path of the centre.

Our alternative was to pass considerably further to the north, to prosecute a precisely similar investigation there, and that in the immediate vicinity of the most dangerous portion of the coast which we had yet seen, and in the event of no success to double Cape Chudleigh, and seek for our station somewhere in the vicinity of Ungava bay.

This, apart from other considerations, would have involved the loss of much of our remaining and increasingly precious time, and such an increased consumption of the coal on hand as might have seriously inconvenienced, if not indeed hazarded, our safe return, though the steamer, on quitting the harbor of Sidney, had taken all the coal that she could well carry, and, through the providence of her commander, a schooner had been chartered to meet us with a new supply, on our return voyage, at a point about halfway down from our station to Sidney.

Penetrating carefully, therefore, the inlet (see Sketch No. 38) in a direction a little towards the southwest, we soon found what presented the appearance of a fine plateau, but which proved, upon investigation, to afford a series of terraces, admitting of a great variety of elevation if belts of fog should be found to interfere, and also shut out, by what proved to be a double range of mountains, from the intrusion of the ocean mist.

The efficiency of this barrier in this very respect exceeded my highest expectations, the mist creeping over, indeed, and descending below the tops of the highest hills, and yet, under ordinary circumstances, but rarely finding its way, even by small portions, within the area thus defended. The harbor thus shielded was, moreover, (in the judgment of the commander,) admirable, the holding ground especially good.

The elevation of the principal station above the level of the sea is 110 feet, while the peaks behind this are 2,150 and 1,729 feet high, respectively. These heights were determined by Prof. Venable, Dr. Barnard, and Mr. Lieber, as is stated in Prof. Venable's report to me, hereto annexed.

The *latitude* of the principal station, at which a small temporary observatory, containing the transit instrument, &c., had been erected, as determined by the observations of Lieut. Ashe, Prof. Smith, and myself, was found to be 59° 47′ 49″ N.; and the *longitude* at present apparent upon comparison of the standard chronometer (Dent, 2602) with the local time is 4*h.* 16*m.* 53*s.* west of Greenwich.*

It seems not inappropriate to insert in this place the report of the frequent comparisons of chronometers made in duplicate by Mr. Goodfellow and myself, the results of the several comparisons being marked with the appropriate initials to indicate the respective observers: A., Alexander; G., Goodfellow; and in one or two instances, T., Thompson.

In the instance of the standard (Dent, 2602) and that of the sidereal chronometer, (Hutton, 207,) the times indicated by each at the same date are given, while for all the others the difference between the chronometer in question and the standard is given, this difference being always that of time of chronometer compared *minus* that of the standard; so that + denotes fast; —, slow.

* Afterwards, when errors from Greenwich time and rates had been well ascertained, found to be 4*h.* 16*m.* 29*s.*—(See Addendum on the longitude by chronometers.)

Date.	Obs.	Standard, Dent 2002.	Bond & Son, 177.	Hutton, 207, (sidereal.)	Arnold & Dent, 802.	Kessel's 1285.	Fletcher, 1739.	Dent, 2126.	Dent, 2167.	Alexander.
1860.		h. ′ ″	′ ″	h. ′ ″	h. ′ ″	h. ′ ″	′ ″	″	′ ″	h. ′ ″
June 29	A.	5 04 00	+ 34 55 4	6 52 44.9	—3 57 59.2	—5 8 29.5	— 14 18.2	— 8.9	+ 41 54.2	......
	G.	......	55.3	44.5	59.2	8 29 7	18.3	— 9.2	54.5	......
30	A.	5 05 00	56.5	6 57 45.9	58.6	39.3	23.8	— 10.1	+ 41 55.1	......
	T.	......	56 5	45.7	58.4	39.4	23.8	— 10.3	55.0	......
July 1	......	(Sunday)....	......	......	......	......	......	......	......	......
2	A.	......	58.6	......	55.2	59.2	33.8	— 11.9	+ 41 58.4	......
	G.	5 02 50	58.3	7 03 37	55.2	60.0	37.0	— 11.7	58.3	— 5 9 03
3	A.	......	59.1	......	50.3	—5 9 10.5	42.3	— 12.4	+ 42 00.5	......
	G.	5 8 11	58.8	7 13 00	51.0	10.3	42.7	— 12.3	00.5	— 5 8 28
4	A.	......	60.1	......	48.6	20.3	48.3	— 12.1	2.8	......
	G.	5 9 9.5	59.8	7 18 00	48.4	20.3	48.3	— 12.3	2.8	— 5 8 30.2
5	......	(No comparison)	......	......	......	......	......	......	......	......
6	A.	......	+ 59.1	......	40.1	43 6	59.0	— 16.7	5.9	......
	G.	5 8 0	59 6	7 24 50	40.3	43.3	58.3	— 16.6	5.8	21.2
7	A.	......	58.6	......	33.4	53.9	— 15 4 4	— 18.1	7.8	......
	G.	5 12 9.5	58 6	7 33 00	33.3	54.2	5.2	— 18.3	8.2	32.8
8	......	(Sunday)....	......	......	......	......	......	......	......	......
9	A.	......	58.1	......	21.2	5 10 15.1	17.1	— 22.3	12.1	
	G.	5 18 18.5	57.7	7 47 9.5	21.3	15.2	17.2	— 22.2	12.7	(*)
10	A.	......	+ 34 57.2	......	—3 57 14.6	—5 10 26.6	— 15 24.1	— 23.9	+ 42 13.9	
	G.	5 11 15.5	57.2	7 44 05	14.6	26.3	23.7	23.5	13.8	......
11	A.	......	56.7	......	8.1	37.5	31.1	25.3	16.0	......
	G.	5 20 54	56.7	7 57 45	7.9	37.4	30.6	25.6	15.2	......
12	A.	......	+ 34 56.0	......	—3 57 1.3	—5 10 48.6	— 15 37.2	— 27.6	+ 42 17.3	
	G.	5 13 50.5	55.7	7 54 40	1.5	48.2	36.8	27.8	17.1	(†)
13	A.	......	56.2	......	56 55.2	59.0	43.1	30.0	19.2	
	G.	5 17 15.5	56.7	8 2 05	54.5	58.9	43.6	29.4	19.7	......
15	......	......	......	......	......	—4 16 22.7				
16	A.	5 54 00	55.1	8 50 54.8	56 36.0	16 27	— 16 02.7	+ 23.0	......	(‡)
20	A.	......	49.3	......	56 1.3	......	28.3	13.0	......	
21	A.	......	45.8	......	55 52 9	—4 17 27.6	34.9	10.0	42 58.7	......
	G.	8 07 3.5	45.8	11 24 10	53.3	27.7	35.0	10.3	58.2	......
22	......	(Sunday)....	......	......	......	......	......	......	......	......
23	A.	......	45 4	......	38.0	48.4	16 47.8	4.4	43 03.8	......
	G.	5 19 7.5	45.5	8 43 45	37.9	48.5	47.7	4.7	3.9	......
25	A.	8 30 52.3	+ 34 46.0	0 4 00	—3 55 35.0	4 18 13.6	17 2.0	—0 0 1.0	+ 43 09.1	......
26	A.	......	46.4	......	20.4	22.3	7.0	3.2	12.4	......
	G.	5 26 42	46.5	9 3 20	20 7	22.4	7.0	3.5	12.7	......
27	A.	......	47.1	......	— 17.0	32.9	12.3	5.2	16.9	......
	G.	5 14 34	47.1	8 55 10	— 17.0	32.5	12.9	5.3	16.4	......
28	A.	......	48.9	......	11.1	44.5	18.1	7.9	20.3	
	G.	6 3 15.5	48.3	9 48 00	10.9	44.5	18.4	7.9	20.7	(§)
29	......	(Sunday)....	......	......	......	......	......	......	......	......
30	A.	......	50.9	......	—3 54 59.6	—4 19 5.6	29.7	11.8	29.0	......
	G.	5 9 4	50.7	9 1 40	59.3	5.4	29.9	12.4	29.1	......
Aug. 1	A.	......	53.7	......	51.8	26.6	41.1	15.6	37.8	......
	G.	5 00 20	53.7	9 00 55	51 4	26.4	41.3	16.1	37.1	......
2	A.	......	55.0	......	— 49.1	38.1	48.1	18.2	40.7	......
	G.	5 28 25.5	54.7	9 33 05	49.2	37 7	47.9	18.4	40.8	......
3	A.	......	56.4	......	45.9	48.4	52.9	20.2	44.7	......
	G.	5 50 31.5	56.5	9 59 15	45.9	48.2	53.4	20.4	44.4	......
4	A.	......	34 58.2	......	3 54 43.8	—4 19 59.5	— 17 59.0	— 0 22.2	+ 43 48.7	......
	G.	6 48 31.5	58.1	11 01 25	43.3	59.2	59.3	0 22.3	48.5	......
5	......	(Sunday)....	......	......	......	......	......	......	......	......
6	A.	......	+ 59.7	......	38.2	4 20 21.2	— 18 11.6	— 27.7	53 3	......
	G.	5 21 2	59 5	9 41 40	38.3	20.8	11.6	28.3	53.0	......
7	A.	......	+ 35 00.9	......	35.9	32.3	17.1	30.2	57.0	......
	G.	6 53 21 5	00 8	11 18 15	35.8	31.9	17.5	30.6	56.7	......

* Chronometer stopped and reset.
† Chronometer stopped from some unknown cause.
‡ Kessel set to mean time, of Δ July 15.
§ Comparison 55 minutes later than on the 27th.

NOTE.—From the recorded error from Greenwich mean time, as reported by the Messrs. Blunt of New York, on the 27th of July, both of the Standard chronometer and of Dent, 2126, as well as from comparison of subsequent rates, it is rendered certain that a mistake of one minute was made in determining the error of Dent, 2126, from the Standard on the 29th of June, and that the error was perpetuated until July 16, inclusive – the *seconds* only having been compared in the interim. One minute should therefore be added to every number in the column of Dent, 2126, to the date of July 16, inclusive: —8s 9 reading + 51s.1, &c.

A comparison of rates has moreover made it abundantly probable that the *seconds* due to *Kessell*, 1285, on the 21st of July, were 37s.6 and 37s.7, respectively, instead of 27s.6 and 27s.7: this being rather to be apprehended, because the figures were noted in pencil and afterwards "inked over." The correction thus indicated has been applied in the computation of longitude by the chronometer in question.

The chronometer employed in making our observations was Bond & Son, 177.

A combination of observations made by Lieut. Ashe, Prof. Smith, and myself, gave for the error of this chronometer at the time of the total eclipse: chronometer too *fast* for mean time (civil reckoning) at the place of observation 4*h.* 51*m.* 58.92*s.*; while another combination of consistent results of my own observations, made both before and after the meridian passages of the sun, gave for the error at the same epoch 4*h.* 51*m.* 57.86*s.*; the mean of the two is 4*h.* 51*m.* 58.39*s.* This must be increased 0.36*s.* if the equation of time as given in the American Nautical Almanac be made use of instead of that given in the British N. Almanac.

As soon after we left New York as was found to be convenient I called together all who were expected to take a part in the observations, and gave them an exposition of the phenomena to be sought for, illustrating my remarks by reference to numerous diagrams as I proceeded.

After this a special assignment of all the observations was proposed, and as far as might be settled.

My secretary, Mr. Henry, then made careful copies of the several programmes, and they were distributed severally to those to whom they belonged. Several matters alluded to in each were also further elucidated by me in personal communication with the observers themselves.

The special assignment was finally made as follows, agreeing in many respects with the preliminary arrangement made in conference at Washington:

The transit observations were assigned to Lieut. Ashe.

We had completed our selection of station and made some preliminary observations on Saturday, the 14th. On Monday the temporary observatory already alluded to was set up. Lieut. Ashe took up his lodgment with his instruments on shore, while Prof. Venable and Mr. Lieber took up their quarters in a tent at the meteorological station; and Messrs. Goodfellow and Walker had their magnetic observatory and encampment completed, they having, indeed, made some arrangements on Saturday. The preliminary arrangements of the meteorologists were, blown down, but were restored on the following Monday.

Lieut. Ashe met with so many obstacles from the interference of daylight, great fickleness of the weather, and almost continual clouds at night, and sometimes also from storms, to say nothing of unexpected mechanical difficulties and obstacles, that, after a persevering and faithful trial, he was compelled to abandon the hope of any result from the transit instrument, and we were obliged to trust to our sextants only.

To Mr. Henry was assigned the charge of calling the *seconds* of time audibly whenever required, while the passing *minute* was watched for and furnished by Mr. Fisher, one of the engineer's assistants.

Mr. Henry was likewise so to arrange as to note the intensity of light during the total obscuration of the sun, by ascertaining the distances at which printed books and the chronometer could be read.

The other special arrangements were as follows:

To Lieut. Ashe, Prof. Smith, and myself, associated as time observers:

Before the beginning:

1. Visibility of the border of the moon before she touches the sun. Time and distance at which the same may occur.

2. Agitation of the sun's limb before the first contact in the region where the first contact may be anticipated.

At or about the time of beginning:

(*a*.) Time and position of the first contact.

3. Adhesions and distortions as the eclipse begins.

4. Dark lines. (Baily beads.)

As the eclipse advances:

5. Early and subsequent distortions of the cusps. Color and shading of the same.
6. Projection of the moon beyond the sun. Time and extent to be noted.
7. Bright band along the moon's edge.
8. Contact with different portions of the solar spots, with distortions, if any. (May be an apparent repulsion; may be a drawing over the luminous material.)
9. Flashes or corruscations of light across the moon.
10. Peculiar color of the moon's disc and of the solar spots.
11. Peculiar illumination of a portion of the moon's disc; also singular spots on the same.

Immediately before the total immersion:

12. Formation of Baily beads.
13. Dark lines beside or among them.
14. Rapid changes of the last visible portion of the sun.

At the total immersion:

(*b.*) Time of total immersion, and point at which it takes place.
15. Flashes or rays as the sun disappears or immediately thereafter.
15 (*bis.*) Superior brightness of the corona towards one side, especially along the moon's border where the sun has just disappeared.
16. The color of this light, whether a red band appear just after the sun has disappeared, and if there be visible a dark line between this red light and the white.
17. Whether the corona consists of two distinguishable portions. Whether, at least, there is not a manifest intensity near the moon, with a rapid degradation, insomuch that the outer portions beyond all this are comparatively quite dilute.
18. Peculiar radiations; also their changes and directions; (perpendicular to the moon's limb, or otherwise.)
19. Don Ulloa's spot.
19 (*bis.*) The lunar spots and shadings.

Just before the emersion:

20. Increased brightness of the moon's edge, and when and where it occurs.
21. The red light along the edge and the dark line between it and the white, to be looked for as before.
22. Flashes or bright points just about the time of the immersion or a little before.

At the emersion:

(*c.*) Time and the *position* of the point at which it occurs.
23. (See margin of preceding page.)*
24. Baily's beads and the accompanying dark lines.
25. Rapid changes of the portions of the sun first visible.

After the emersion of the total eclipse and before the end:

26. Flashes; color of the moon; illumination of the disc, as before.
27. Bright band again.
28. Projection of the moon beyond the sun.
29. Contact with the solar spots and distortions, &c., of same as before.

At the end of the eclipse:

30. Distortions and adhesions, (Baily's beads.)
(*d*) Time of last contact.
31. Agitation of the limb where the moon left.
32. Whether the moon is visible beyond the sun; time and distance at which the same may occur.

* On which was written, crosswise—23 Differences in the appearances as seen by the bare eye.

To President Barnard:

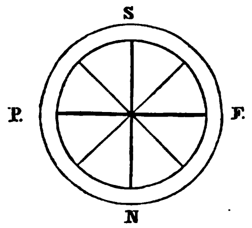
Before the beginning:

(*a*) Visibility of the border of the moon before she touches the sun; time and distance at which the same may occur. (Observations to be made by reflexion from an artificial horizon.) Afterwards variation in intensity of light and color of the sky, clouds, and landscape.

During the time of the total eclipse:

Being seated at the telescope a little before to observe with respect to the *red* or *violet* clouds.

1. The time of their first appearance, or, if one should appear later than another, their several times.
2. Their position by means of an arrangement of wires or lines in the diaphragm of the telescope, as represented in the following drawing:



The bold line P F being adjusted by the diurnal motion nearly parallel to the equator.

3. Their size, form and growth, or other changes of form.
4. Their color and its changes.
5. Try the color through various screens.
6. The width of the corona, as compared with the distances between the rings of the micrometer and whether its breadth around the moon is uniform. Incidentally, as the eclipse diminishes, projection of the moon beyond the sun.

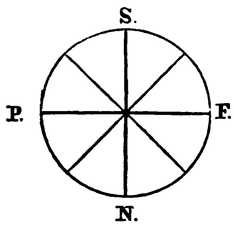
At the end of the eclipse:

Visibility of the border of the moon after she has left the sun; time and position as before.

To Prof. Venable:

Before the eclipse:

1. Position of the solar spots by an arrangement of wires or rings in the diaphragm of the telescope, thus:



The bold line P F being adjusted by the diurnal motion so as to be nearly parallel to the equator.

At various times, just before, during, and after eclipse.

1. Visibility of the border of the moon before she touches the sun; time when this may occur and the distance from the sun.

NOTE.—The arrangement for an artificial horizon could not be carried into effect for a telescope of the size of that used by Dr. Barnard, but it was prepared for his associate, Lieut. Comg. Murray, who observed with the telescope of a sextant, and was successful in detecting the phenomenon in question, viz: the projection of the moon's limb beyond that of the sun, as stated in the report under its appropriate heading.

2. Polarization of the atmosphere.
3. Changes in the intensity of light as the eclipse advances.

Just before the total eclipse:

The time of the first appearance of the corona and the part of the moon's border where it thus appears.

During the total eclipse:

With respect to the red or violet clouds to observe—

(*a.*) The time of their first appearance, or, if one should appear later than another, the several times.
(*b.*) Their positions, as near as can be estimated, or else by the arrangement of intersecting lines, if they can be introduced.
(*c.*) Their form, size, and growth, or other changes of form.
(*d.*) Their color and its changes.
(*e.*) Try the color through various screens. Notice, if it may be, whether the corona is of uniform breadth all around the moon.

After emersion from the total eclipse:

4. Flight of the shadow.
5. Changes of the intensity of the light as the eclipse recedes.
6. Visibility of the moon after she leaves the sun. Time, &c., as before.

At some convenient time, in conjunction with the commander and Mr. Lieber:

Elevation of the station above the level of the sea.

Miscellaneous:

Plan of meteorological observations is already understood.

Mr. Lieber:

Temperature (according to plan) in shade and sun, in conjunction with Professor Venable.

Observations of the dew-point.

Barometric observations.

Polarization of the corona.

Color of the sky, clouds, and landscape, and direction of clouds; force and direction of the wind.

Topographical sketch of station.

Geological description of station.

In conjunction with the commander and Professor Venable:

Elevation of the station above the level of the sea.

Lieut. Comg. Murray:

Tidal current, deep-sea soundings, and temperature observations; also topographical and flying survey of the station, as enumerated by the Superintendent.

Observations specially connected with the eclipse:

Elevation of the station in connection with Professor Venable and Mr. Lieber.

Before the beginning:

1. Visibility of the border of the moon before she touches the sun, (to be tried with a telescope looking into an artificial horizon; better a horizon of oil than of mercury;) time when this may occur, and the distance from the sun.

Incidentally, in conjunction with time observers:

At the beginning:

(*a.*) Time of first contact, as seen in artificial horizon.

Between the beginning and the total eclipse:

(*b.*) Bright band along the moon's edge.

(*c.*) Distortion of the cusps; color and shading of the same.

(*d.*) Projection of the moon beyond the sun.

(*e.*) Contact with different portions of the solar spots, with distortions, if any; (may show an apparent repulsion, or may exhibit a drawing over of the luminous material.)

(*f.*) Flashes, or corruscations of light across the moon.

(*g.*) Peculiar color of the moon's disk and of the solar spots.

(*h.*) Peculiar illumination of the moon's disk; also singular spots on the same.

Just before the total obscuration:

2. First appearance of the corona, and the position of the portion at which it first shows itself.

During the time of the total obscuration:

3. A search for the supposed new planet.
4. Number and position of stars; and whether any of them are red, or otherwise colored.

Just before the immersion:

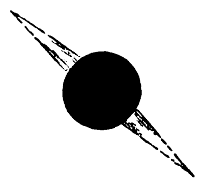
5. Bringing back the telescope to the sun, to observe whether the corona lasts after the emersion of the first beam of light; and if so, how long; when it ceases to be seen; and around what part it is last visible.

To Mr. Robert Platt, acting sailing-master:

1. Changes in the intensity of the light as the eclipse advances.
2. Whether, just before the total eclipse, long stripes of light and shade are to be seen moving across the landscape, and if any of these are colored.
3. Whether there is not a sensible quiver or tremor in the last beam of light visible at the total eclipse, just before the same disappears; whether, at the same moment, the shadows of bodies are wavering, or colored at the borders.

When the sun is totally hidden:

(*a.*) To notice whether a faint beam of light extends from the eclipsed sun, or beyond the corona, on both sides, in this direction.



(*b.*) Whether, in the progress of this scrutiny, the comet is visible.

To observe the extent of the corona with the bare eye and with an opera glass; and whether the outside, or any other part, be colored; and whether the corona has any motion.

To Messrs. Du Barry and Wilson, master's mates:

To observe in the camera obscura before the eclipse begins:

(*a.*) Whether the image of the moon be visible before she touches the sun; also the time when this happens, and the distance from the sun's limb.

After the beginning, and before the total eclipse:

(*b.*) Whether a bright band be visible, bordering the edge of the moon's image, especially soon after the beginning of the eclipse, and also when the eclipse is largely advanced; same soon after the total eclipse, and near the end.

(*c.*) Any distortion or any coloring of the cusps, and the time when the same may occur.

(*d.*) Color of the moon's image, or of solar spots, especially any peculiarity in the same when viewed through various colored glasses.

During the total eclipse:

(*e.*) To mark the extent of the corona, and the position and form, &c., of the colored spots around the dark body of the moon.

(*f.*) To note the extent and mark the boundary of the corona.

(*g.*) To ascertain the effect of colored glasses on the spots and on the corona.

After the eclipse:

Repetition of observations before, viz: those marked (*b*,) (*c*,) and (*d*,) respectively.

Mr. Du Barry to pay especial attention to the effect of the colored glasses, and Mr. Wilson to the marking of positions. This division of labor will be especially necessary during the brief period ($3\frac{1}{4}$ minutes) of the total eclipse.

To Mr. French, chief engineer :

Approach of the shadow from the west just before the total eclipse, as seen in the darkening of both the sky and the earth; and whether dark stripes are not seen flitting across the landscape just before the eclipse is total; and whether there is not a tremor of the last visible beam of the sun.

Force and direction of the wind; whether it is increased, or not, as the total eclipse comes on; and whether it blows *from* the shadow as the shadow approaches, and again back from the shadow as it recedes; and whether there is a *lull* in the middle.

Whether either the aurora or comet is visible.

Flight of the shadow eastward.

To Mr. Nones, assistant engineer :

The approach of the shadow from the west, as seen by its darkening the sky and the landscape.

Tint of the sky, especially overhead; also that of the clouds, and the direction of the clouds.

If any stars are noticed, to observe their color, especially that of one near the zenith; see, especially, if any be *red.*

To notice if there are any traces of the aurora borealis.

To observe the intensity of the light during the total eclipse, by noting how near the eye must be brought to see the seconds on a chronometer; also, how near the eye must be brought to read several sizes of print, marking the distance in inches at the bottom of the page in pencil; and remembering or noting also the distance for the chronometer, and whether the light increases towards the middle of the eclipse.

Flight of the shadow eastward.

Then, as soon as may be after the total eclipse—

To notice whether the flowers have closed their blossoms.

To Mr. Osborne, surgeon's steward :

1. Electrical observations.
2. Approach of the shadow from the west, as seen by the darkening of the sky and landscape.
3. Force and direction of the wind; especially whether the wind is increased as the dark shadow approaches, and is *from* the shadow as the shadow approaches, and again *back* from the shadow as it recedes; and whether there is a lull in the middle.
4. Whether there are any traces of the aurora borealis; or whether the comet can be seen, or any *red* stars.
5. Whether the circle of light around the moon appears broader towards any one side; and, if so, which?

At the suggestion of Professor Venable, I also drew up a list of phenomena to be looked for by the seamen. It was committed to the care of Lieut. Comg. Murray, who kindly undertook

to have it properly communicated to the seamen. Through him, also, I received their report, which will be found to contain some valuable items, and which appears in its proper place. The programme which I prepared for them is as follows:

To be noted by the seamen:

1. The fading of the light, and the color of the sky, clouds, and landscape.
2. Whether they can see a star a little below and to the right of the sun *before* the eclipse is total, and for a little while after the sun begins to be seen again.

   After the eclipse is total:
3. Color of the sky, the landscape, and the clouds.
4. How many stars they can see, and their color; if any were *red* when they saw them.
5. The approach of the shadow, as shown by the darkening of the sky and landscape towards the west.

The degree of darkness; to be noted by seeing how near, in inches, the eye must be brought to read a printed page; the number of inches to be marked on the book, so as to be recorded afterwards.

Dark and light stripes flying over the ground just before the total eclipse.

Also, the quivering of the last beam of the sun just before it disappears.

6. At the same time, the like motion in the edges of the shadows: perhaps, too, the edges of the shadows may be colored.
7. Size of the bright ring around the moon; noticing whether the ring is a quarter as broad as the dark moon, or twice as broad, or how many times.
8. Whether the force of the wind is *increased* as the shadow approaches; and whether the wind then blows *towards* us from the shadow; and whether, as the shadow leaves it blows *back to us* again from it; and whether there is a *lull* in the middle of the total eclipse.

Description of the telescopes employed.

The telescopes were all achromatic refractors.

That made use of by myself was made by Utschneider and Fraunhöfer, aperture nearly three inches; focal length of object glass, fifty-one inches; amplifying power about eighty, for the partial eclipse. That used at the total obscuration not yet determined; aperture reduced when the sun was bright.

Dr. Barnard used the telescope obtained from Columbia College, New York; aperture three inches; focal length, forty-five inches.

Lieutenant Ashe used a forty-two-inch Dolland, aperture (probably) not far from three inches; amplifying power about forty.

Professor Smith had a telescope by Plössl of three inches aperture and thirty-two inches focal length; diagonal eye piece; amplifying power not yet ascertained.

Professor Venable, a Dollond of about forty inches focal length of object glass; aperture three and a half inches, nearly; amplifying power not yet ascertained.

Lieutenant Commanding Murray, for some observations, made use of a large comet seeker, by Fritz; aperture, seven and a half inches; focal length, five feet; power low. For other observations he made use of the telescope of a sextant, as hereafter described.

The photographers made use of a five feet refractor by Fritz; aperture four and a half inches. (This description, though confessedly imperfect, is all that can at present be given.)

The telescopes had secure foundations constructed of sand, gravel, and large stone; sometimes packed hard in boxes and portions of casks to bind the supports laterally; then, such as required to be adjusted equatorially were brought nearly into place on the day before the eclipse, and

although the sudden outburst of stormy weather compelled a partial dismounting of the instruments the same evening, yet all were in place for a preliminary drill next morning.

The construction and arrangement of a separate building for a camera obscura could not be effected until almost at the last moment, when there was so much else to do. Then, to my very great regret, I found that our spare telescope, already in place, did not admit of such an adjustment of the eye piece as would give a distinct image; I spent some minutes of the last preparatory hour in trying to arrange it, but without success; so that, although we had a divided circle, and a vertical and a horizontal movement of screen, all ready for marking positions, I was compelled to abandon the whole.

A brisk wind, W. by S., seemed to be carrying the floating clouds before it, and this, together with the breaking of the clouds, gave an almost immediate prospect of a clear sky behind them, and thus gave us hopes that the phenomena might be successfully observed, especially if the wind should somewhat abate; for when the weather became clear at all, our experience had shown it to be very clear.*

The violence of the wind did, indeed, abate, but the clouds were not all dispersed, though large openings appeared. How far the clouds interfered will, however, be gathered from the synopsis herewith presented of the observations themselves.

SYNOPSIS OF THE OBSERVATIONS.

1. In accordance with the plan already exhibited, the moon was sought for before the first contact, by Dr. Barnard and Lieut. Comg. Murray, but without success.

2. *Agitation of the sun's limb near to the point of first contact.*—An agitation of the sun's limb, near to the computed point of first contact, was suspected by me some seconds before the indentation was observed, but the appearance was not sufficiently decided to be accepted as real.

TIMES OF THE CONTACTS.

3. *The observations of the times of the four principal contacts* are here arranged together for convenience of reference.

Beginning of the eclipse.

Time by chronometer. h. m. s.		Observer.
1 0 3.4		Alexander.
56.0†		Ashe.
8.0	estimated.	Barnard.‡
11.0	certain.	Barnard.‡
14.5§		Smith.
15.0		Venable.

Total immersion, or beginning of the total obscuration.

2 5 27.0	(Last fragment lost in clouds.)	Smith.
23.0		Barnard.
29.0		Venable.
29.8		Alexander.
32.0		Ashe.
32.0		Murray.

* This state of things did not enforce upon me the separation of the astronomers, (who could, indeed, hardly have then been fixed for *steady* observation elsewhere,) and the state of things when the total obscuration took place would have rendered such an arrangement, almost to a certainty, useless.

† Believed to have been 6s.0, instead of 56s.0. Correction assented to, as probable, by Lieutenant Ashe.

‡ See Dr. Barnard's report, annexed to this. § See Professor Smith's report.

End of the total obscuration.

Time by chronometer.			Observer.
h.	m.	s.	
2	8	28.8	Ashe.
		30.0	Alexander.

End of the eclipse.

3	17	0.3	Murray.
		1.0	Ashe.
		1.0	Smith.
		1.0	Venable.
		1.7	Alexander.
		2.0	Barnard.

SAME IN MEAN TIME (CIVIL RECKONING) AT THE PLACE OF OBSERVATION.

Beginning of the eclipse.

Time.			Observer.	Color of screen.
h.	m.	s.		
8	8	5.0	Alexander	Green.
		7.6	Ashe	Orange.
		9.6 estimated.	Barnard.	Compound.
		12.6 certain.	Barnard.	Red and green.
		16.1	Smith	Neutral.
		16.6	Venable	Green.

Total immersion, or beginning of the total obscuration of the sun.

9	13	28.6 [Last fragment lost in clouds]	Smith	Neutral.
		29.6	Barnard.	
		30.6	Venable	Bare eye.
		31.4	Alexander	No screen.
		33.6	Ashe	No screen.
		33.6	Murray	No screen.

End of total obscuration.

9	16	30.4	Ashe	No screen.
		31.6	Alexander	No screen.

End of the eclipse.

10	25	1.9	Murray	Red.
		2.6	Ashe	Orange.
		2.6	Smith	Neutral.
		2.6	Venable	Orange.
		3.3	Alexander.	Neutral.
		3.6	Barnard	Compound red and green.

NOTE.—The times thus reduced should in every case be diminished 0s.4, if the equation of time, as deduced from the *American Nautical Almanac*, be substituted for that obtained from the *British Nautical Almanac*.

I felt well satisfied with my own observation of the first contact, and it is confirmed by the photographic impression No. 1, which was taken at the moment that the call was made for the minute, some ten or twelve seconds later. The precise second at which this occurred was not seized upon, though most of the other impressions afterward have the exact second recorded.

The observation which I made of the total immersion was also satisfactory. Of the emersion from the total eclipse I was doubtful between two seconds, the clouds interfering too much; but the time agrees very well with that reported by Lieut. Ashe, who was the only other observer who caught the emerging beams, if indeed he was not the only one who actually saw the very first emersion, for he described the first visible portion as having appeared to him like a bright star.

The positions of the points of contact, as near as they could well be estimated, will be apparent from the diagram here presented. (No. 1, Sketch No. 39.)

OTHER OBSERVATIONS.

(4.) *Bright band bordering that edge of the moon which was projected on the sun's disc.*—This phenomenon, first noticed by myself in 1831, and to which I have on various occasions called the attention of others, was visible on this occasion in my telescope at about 8*h.* 13*m.*,* and especially at 8*h.* 17*m.* 15*s.*

The phenomenon was more distinctly visible through the *green* and the *blue* screens, respectively, than those which were *violet* or *neutral*, and above all through that of an *orange* tint. Again, at 9*h.* 39½*m.*, the *orange colored* screen showed the phenomenon by far the best—then *violet*, *green*, *blue*, in their order; *neutral tint* the least.

Prof. Venable saw the sun brighter along the border of the moon, though he hesitates to call the appearance a bright band; time, 8*h.* 15*m.* 10*s;* and at several other times in the progress of the eclipse saw it through *green* and through *orange* screens, respectively.

Prof. Smith remarked, after the first immersion, and till the moon approached a dark spot, a *yellow* band separated from the white light of the sun by a distinctly dark line. This he states was seen in the centre of the field, and was not due to any lack of achromatism there, at 9*h.* 36*m.* 17*s.*

Prof. Smith again saw the light, in connection with a peculiar illumination of the moon's disc, to be more fully described hereafter.

He made use of a *diagonal eye-piece*, as before stated, and his screen glass exhibited a *neutral* tint.

Lieut. Commanding Murray noted, at 9*h.* 37*m.* 13*s.*, a bright yellow border; and at 9*h.* 44*m.* 11*s.* a bright edge around the moon; *i. e.*, the part of it projected on the sun's disc. Also a discernible line around the portion of the edge yet remaining projected at 9*h.* 46*m.* 30*s.*

It will be remembered that his telescope was the large comet-seeker; his *screen glass* had a *red* color.

The phenomenon in question is distinctly represented in the photographic plates; the light from *near the border of the sun* being most perceptibly affected—as I have heretofore had occasion to observe in other instances.

Photography has also before this confirmed all that is here related. The bright band is unquestionably pictured in the copies of daguerreotypes of the eclipsed sun taken at Mr. Campbell's observatory in New York, under the supervision of Mr. Campbell and Prof. Loomis, in May, 1854.

(5.) *Roughness of the moon's edge, and a distortion of the cusps* (*one or both*) *of the uneclipsed portion of the sun.*—This roughness is distinctly represented in photographic plate No. 1, which was taken a few seconds after the beginning of the eclipse; and in other of those plates, taken when the light along the moon's edge came from near the sun's border.

Lieutenant Ashe mentions two high mountains of the moon, which he saw at the immersion, just under the upper cusp.

A distortion of the sun's (apparent) upper cusp was noticed by Professor Venable at 8*h.* 15*m.* 10*s.*, (screen glass *green ;*) also at 8*h.* 59*m.*, (screen glass *orange ;*) again, at 9*h.* 4*m.* 6*s.*,

* The times subsequently noticed in this synopsis are the mean times (civil reckoning) at the place of observation. Equation—the American.

he noticed the edge of the moon rougher at the upper cusp, (screen glass, *orange;*) also, at 9*h.* 4*m.* 59*s.*, distortion much greater, (screen glass *orange.*)

At 9*h.* Professor Smith saw the (apparent) lower cusp slightly distorted, or curved inward towards the centre; diagonal eye-piece, (screen glass *neutral.*)

At ——, (time not given,) Lieut. Comg. Murray describes the edge of the moon as being roughened; again, both cusps distorted, (screen glass *red.*)

At 9*h.* 5*m.* Professor Smith says that the concavity of the (apparent) lower portion of the crescent appeared irregular. It was indented in two places; and at 9*h.* 6*m.* another indentation was seen further up, it being about twice as far from the cusp as the second of the preceding ones, (that seen at 9*h.* 5*m.*;) diagonal eye-piece, (screen glass *neutral.*)

My own notes mention, at 9*h.* 15*m.* 10*s.*, a distortion of a cusp, probably the lower one—(vision erect;) at 9*h.* 18*m.* 32*s.*, a slight distortion of both cusps, (screen glass, *neutral;*) at 9*h.* 32*m.* 56*s.* Lieut. Comg. Murray saw the lower cusp cut off, (screen glass *red.*)

Professor Venable saw a blunting of the upper cusp at 9*h.* 33*m.* 51*s.*, (screen glass *orange.*)

Lieutenant Ashe reports the (apparent) lower cusp as being blunted, and, at the same date, my own notes state the same thing, but with respect to the *lower* cusp, vision erect, as I have supposed; but it may have happened before I changed the eye-piece; (screen glass *orange* for the one, probably *neutral* for the other.)

At 9*h.* 33*m.* 56*s.* Professor Smith also saw the (apparent) upper cusp cut off, or rounded; and, at 9*h.* 40*m.*, the upper end appeared bifurcated; one of the divisions being prolonged beyond the others, thus:

Diagonal eye-piece; (screen glass *neutral.*)

Lieut. Comg. Murray reports rough edges at 10*h.* 19*m.* Irregularities were also noticed by Dr. Barnard. It may be observed, in general, that the roughness was the most strikingly conspicuous of all a very short time before the total obscuration, when all the light was *border* light, as will be more particularly described in (10.)

(6.) *Contact with solar spots.*—At —*h.* —*m.* 14*s.*, a contact; observer, Lieut. Comg. Murray.

At 8*h.* 20*m.* 36*s.*, contact with the penumbra of a large spot, but vision was indistinct on account of a cloud; observer, Professor Smith.

At 8*h.* 21*m.* 9*s.* to 11*s.*, my own notes mention a contact with a penumbra; slight cloud passing.

At 8*h.* 21*m.* 28*s.*, immersion of a large spot; Professor Venable: also at 9*h.* 1*m.* 20*s.* the apparent lower one of two, and the upper one at 9*h.* 1*m.* 58*s.* began to be submerged; and the upper one was entirely covered at 9*h.* 4*m.* 6*s.*

My own notes mention, at 9*h.* 1*m.* 25*s.*, contact with the penumbra of a spot; at 9*h.* 1*m.* 36*s.*, contact with the dark spot; at 9*h.* 1*m.* 50*s.*, immersion of the same; at 9*h.* 1*m.* 59*s.*, immersion of penumbra. At 9*h.* 1*m.* 30*s.*, Dr. Barnard observed the immersion of a spot.

At 9*h.* 1*m.* 34*s.*, Professor Smith reports a contact with a small spot in the (apparent) SW. quadrant, (actually SE.;) at 9*h.* 1*m.* 48*s.*, the spot was totally obscured. At 9*h.* 1*m.* 53*s.*, and 9*h.* 2*m.* 8*s.*, Dr. Barnard again reports immersions; and Prof. Smith, at 9*h.* 1*m.* 58*s.*, a contact with second small spot; at 9*h.* 2*m.* 5*s.*, a contact with lower one of the group.

The following are reported by Lieutenant Ashe: contacts at 9*h.* 2*m.* 10*s.*, and 9*h.* 2*m.* 33*s.*

Emersions were observed, at 9*h.* 29*m.* 44*s.*, of a spot, and at 9*h.* 30*m.* 26*s.*, of a border of a spot, by Dr. Barnard; at 9*h.* 29*m.* 53*s.*, centre of a spot, by Lieutenant Ashe; and Prof. Venable observed the emersion of a large spot at 9*h.* 29*m.* 54*s.*

Other emersions.

Times.				Observers.
h.	*m.*	*s.*		
9	37	8		Barnard.
9	59	23		do.
10	2	34	(small spot)	Alexander.

Times.			Observers.
10	6	48	Barnard.
10	8	13	do.
10	10	48	do.

Colors of screen glasses.

Lieut. Comg. Murray's	Red.
Professor Smith's	Neutral.
Lieutenant Ashe's	Orange.
Doctor Barnard's (compound)	Green and red.
Professor Venable's	Orange.
Professor Alexander's	Neutral.

(7.) *Flashes or corruscations of light across the moon.*—Professor Smith remarks that, at 9*h.* 12*m.*, the entry was made in his note-book of blue flashes, but that he is unable to recall or locate them.

(8.) *Illumination, or peculiar color of the moon's disc.*—Professor Smith reports that, at 9*h.* 9*m.*, a narrow red line or band was seen skirting the moon's border, and apparently on the moon's surface. He says, moreover, that, "at 9*h.* 36*m.* 17*s.*, the moon presented, more distinctly than any time before, the appearance of a hemisphere, and the definition of all portions of the phenomenon more perfect, as if seen through the most perfectly transparent atmosphere. At this time a blue band of considerable breadth surrounded that portion of the moon which covered the sun. This band appeared to be made of radiations of blue light of different degrees of intensity, in a direction perpendicular to the sun's surface. It was bounded by a well-defined line on the moon's surface. I was instantly reminded of the 'mirage' so frequently witnessed on our voyage to this place, in which the horizon appeared to be skirted by a blue sea-wall. The resemblance to an unbroken sheet of water, (varying in thickness or irregularity of surface so as to vary the shading,) falling over a mill-dam, occurred to me. At the base, where it was in contact with the sun, was a very narrow band or line of yellow light, as noticed in diagram No. 2;" (our own, No. 4, sketch No. 39.) Diagonal eye-piece; (screen glass *neutral.*)

The effect of this is distinctly and beautifully registered on photographic plates Nos. 6, 7, 8, and 9, respectively, as is stated also by M. Duchochois and Mr. Thompson in their report.

At 9*h.* 38*m*, 13*s.* Lieutenant Comg. Murray reports "a bright yellow border to the moon;" and, at 9*h.* 44*m.* 11*s.*, "a discernible line around the edge of moon in contact" with the sun's disc, as already stated in (4.)

I have received from Professor Smith the following additional notice of these phenomena, under the date of November 3. He says:

"At the time that the whole hemisphere of the moon towards the earth was visible, the appearance was that of the rough surface of the ocean just at late twilight in the evening, with one's back to the west.

"The appearance of the water in one of the stereoscopic views of an iceberg, when seen with rather faint light, resembles the appearance of the moon at the time. The background was that of very early dawn—a slightly roseate hue, fading away into indistinctness from the sun. The moon appeared to hang out in space midway between us and the sun. No object was ever made to stand out more completely in a stereoscopic picture than did the moon. The duration was not more than two seconds. It disappeared as by a diminished transparency of the atmosphere at first, and then came those floating clouds which annoyed us so much.

"I regret that it did not occur to me to be more specific on this point when I made my partial—or, as I supposed, informal—report when on the ground. No memorandum was made of the phenomenon at the time. I had just cast my eye down on my book to record the appearance of the blue band, and, on looking in the instrument again, the view so overwhelmed

me that I was for some time lost to every other consideration. It haunted my mind continually afterwards, and often now returns with great vividness."

It ought, as it seems to me, to be noted, in this connection, that Professor Smith's eye was, of all those of our company, *the least sensible to color*, under ordinary circumstances.

(9.) *Projection of the moon's disc beyond that of the sun.*—As I had, as I thought, ascertained that, in other instances, this phenomenon could be better seen when the image of the sun, reflected from oil, was viewed with a telescope, instead of the sun itself, Lieut. Comg. Murray, at my request, made use of an artificial horizon of oil, defended from the wind by the ordinary pent-house, as intimated in the programme furnished to him.

Viewing the sun in this way with the telescope of sextant, Lieut. Commanding Murray, at 9*h.* 44*m.* 11*s.*, saw the moon's disc extending beyond the sun's cusps some 15° on both sides.

Acting Sailing Master Platt repeated the observation with the same instrument, and with a similar result, (screen glass *rose color.*)

Among my own notes I find this phenomenon mentioned as having been seen at 9*h.* 43*m.* 10*s.*, (screen *blue;*) also at 9*h.* 45*m.* 18*s.;* extent about 8° from the upper cusp, (erect view;) screen glass *neutral.*

At 9*h.* 43*m.* 44*s.*, Prof. Smith speaks of a bluish light flashing around the lower limb of the moon from the sun's disc, having a curvature the same with that of the moon, seeming for a moment to reveal the border of the moon beyond the sun's disc. (Diagonal eye-piece; screen *neutral.*)

Lieut. Ashe could frequently follow the edge of the moon off the sun 3° or 4°, mentions the phenomenon especially in connection with that of the breaking off of the (apparent) lower cusp at 9*h.* 33*m.* 55*s.*

(10.) *Breaking of the visible portion of the sun into fragments a very short time before the total obscuration. Dark lines; Baily beads.*—This was a very striking and beautiful phenomenon. Some seconds before the last remnant vanished it became rough and jagged; all the remaining portion of the sun presenting in its inner outline very accurately the appearance of the bright portion of the moon as seen in the telescope as soon as she is visible after the new moon; the southern cusp withal being that most affected. (Fig 5, Sketch No. 39.)

It was not until the crescent-shaped fragment became *very narrow* that the phenomenon became conspicuous. I did not observe any tendency to the formation of the "Baily beads," but the remnant of the sun seemed to be broken up and melted away, as a highly ignited metal might be under the influence of intense heat, the whole being very similar to the beautiful rupture of the narrow ring of the annular eclipse which I saw in 1831.

The actually inferior brightness of the sun's border light and the constantly recurring veil of passing clouds together made it possible for me to contemplate the whole without the intervention of a screen. Lieut. Ashe also removed his screen glass eight minutes before the total obscuration.

At 9*h.* 7*m.* 18*s.*, Prof. Venable observed "the formation of a bead" at the upper (southern) cusp; "saw two or three form;"* (screen glass probably *green.*)

Prof. Smith states that at 9*h.* 12*m.* 42*s.*, dark lines appeared, dividing the (apparent) upper portion of the fine silvery line of the sun's disc, giving to it a fragmentary appearance; the lower portion was indistinct, being partially concealed by clouds. (Diagonal eye-piece; screen *neutral.*)

The times at which I myself marked the early appearance and subsequent progress of the phenomenon in question were very nearly as follows: 9*h.* 11*m.* 17*s.*, 9*h.* 13*m.* 17*s.*, 9*h.* 13*m.* 25*s.*, the last mentioned date being about six seconds previous to the total immersion.

Lieut. Ashe remarks that when the bright crescent was reduced to a thin line of light it was

* Time: about 6*m.* 12*s.* before that of the total obscuration.

a beautiful object to behold, extending about 130° round the edge of the moon; and he adds that shortly afterwards it broke up into fragments.

(11.) *Rapid changes in the last visible fragments and agitation, or quivering of the last beams of light.*—Lieut. Ashe says of the fragments into which he saw the remnant broken that "they seemed to swim from the centre towards the cusps." (*No screen.*)

The report of the seamen stationed on shipboard, as rendered by Purser's Steward Collins, speaks of the quivering of the beams, but as being very slight.

12. *Appearance of dark or variegated stripes passing across the landscape, and agitation of the same.*—The report of Purser's Steward Collins also says: "We saw a few shades in the S.SE.," (magnetic, *i. e.*, E. by S.,) and "we observed a slight quivering in the shadows as they flitted across the landscape, and that likewise they were of different colors; red, green, and a yellowish white."

(13.) *Diminution of light as the eclipse advanced, and appearances during the total eclipse of the sun.*—At 8*h.* 39*m.*, Lieut. Commanding Murray notes the darkness as having been first perceptible.

My own notes mention that at 8*h.* 38*m.* 45*s.*, the sky was deepening its blue, and at 8*h.* 45*m.*, the color is described as being smaltz blue. At 8*h.* 58*m.*, it had a purple tint. These several appearances are those of the sky as seen between the patches of very white clouds.

Dr. Barnard describes the change as being "the waning of brilliancy into something like the feeble and ineffectual radiance so observable occasionally in the winter days of New England;" and adds that "after this the daylight took on a more lurid character; the landscape appeared dull and cheerless, yet I could not perceive any change in tints of the objects at hand."

"The sky," he says, "was very beautiful. At 8*h.* 38*m.*, I was very much struck with the intense blue of the sky overhead, and also in the interstices of the clouds in the vicinity of the sun."

"The clouds themselves being fleecy and thin presented a vast variety of fantastic forms of the intensest and purest white, and these by their strong contrast brought out the deep tint of the sky more strikingly. At the hour just named the clouds covered about nine-tenths of the heavens."

At about "9*h.* 8*m.*," or "just before the total immersion, I once more noticed the tint of the uncovered sky, and found its darkness greatly increased. It was still purely blue, but with a depth of azure almost equal to that of the ocean."

At 9*h.* 7*m.*, Prof. Venable speaks of the blue-green tints of the mountains, and the deeper one of their shadows as being very beautiful.

Lieut. Ashe says (about 8*m.*, before the total eclipse:) "At this time I looked round upon several objects that were highly illuminated by the sun before, but now a great change had taken place; a gloomy, unearthly light fell upon all objects, impressing me with the idea that some fearful calamity was about to happen; and I can well imagine that armies engaged in deadly strife would lay down their arms when nature cast so ghastly a light upon the battle-field."

From the various accounts of Acting Sailing-Master Platt, the assistant engineer, Mr. Nones, the surgeon's steward, Mr. Osborne, and the seamen's report made by Purser's Steward Collins, we obtain very similar information as to the deepening tint of blue of the sky. The clouds are spoken of as grey.

At the time of total obscuration.—Just before the total obscuration, Mr. Henry observed that the clouds in the region of the sun were of a copper color, and when the total obscuration had taken place we may gather from the various descriptions in the appended reports, that the clouds at a considerable altitude had a leaden color, while nearer to the horizon, and especially to the regions north and south, which seemed to be beyond the dark shadow, red and a beautiful

orange color were predominant, the rich orange being most conspicuous near to the southern horizon, and the red towards the north.

"The redness of the horizon," says Dr. Barnard, "was remarkable in the north chiefly, perhaps because the north was the only point of the compass which furnished a horizon down to the sea. Looking in that direction the appearance was very like what we see nightly at about 11 o'clock."

"It is, however, to be observed that the obscuration of the greater part of the heavens, and particularly of the region of the sun by clouds, contributed to the remarkable resemblance between their light and twilight. In the northern horizon there happened to be but few clouds."

"But while the aspect of the lower heavens bore so strong a similarity to the ordinary appearance of twilight, it cannot be said that the general aspect of nature, or the kind of illumination that prevailed was devoid of a certain singularity which it is difficult to describe, and which I have never witnessed under other circumstances."

"It was on this account that, remembering the statements which have been made of the funereal gloom and death-like pallor observed in similar moments before, I looked carefully at the faces of those who were nearest to me, in order to detect, if possible, any such traces there."

"I perceived no such change in any of the countenances about me."

Mr. Lieber speaks of the clouds to the east as being *purple*.

Lieut. Ashe says "the light is totally different from that of morning and evening."

These phenomena strongly resembled those described by Mr. C. Piazzi Smith, the astronomer royal of Edinburg, in his account of observations made at Bue island, Norway, in July, during the total eclipse of 1851; and the whole appearance was exceedingly like that which he has so finely delineated. (Edinburg Ast. Obs., vol. XI, page 275, and Plate No. 7.)

(13 *bis.*) In connection with this account of the diminution of light, it may be mentioned that at 10*h.* 8*m.*, when the sun was yet partially eclipsed, the solar faculæ appeared with uncommon distinctness on a part of the sun in the neighborhood of the moon, and towards the upper cusp, though still some distance from the sun's border. (First noticed by Lieut. Ashe, and then and later by all or nearly all the observers. See reports.)

(14.) *Approach and departure of the dark shadow.*—Acting Sailing-Master Platt, whose attention had been particularly directed to these in the programme of phenomena to be looked for, saw the darkness advance from the west with a frightful rapidity, and then pass over. It appeared like a dark column or a very dark cloud.

Mr. Nones speaks of the latter part of the shadow as being of a "dark rose color, which could be traced in the valley below."

The approach of the light following the shadow was very distinctly to be marked.

(15.) *Intensity of light during the total obscuration of the sun.*—Lieut. Ashe remarks that the degree of darkness was not so great as he would have imagined; he could see the remarks in his note-book without much difficulty.

Dr. Barnard says: "The darkness was not such as to incommode me in performing any ordinary work. I looked up the bay towards the north, and could have distinguished persons and boats at a great distance." Found that he could write with a pencil, and read what he had written with great facility: found no difficulty in reading his notes in any position.

Prof. Venable found that in order to read a newspaper he was obliged to bring it within four inches of his eyes; much nearer than usual.

Mr. Henry read a part of Dr. Hayes' Arctic Boat Journey with which he was not familiar, at a distance of six inches, and a much smaller type (about the size of that of which specimens are given by Mr. Nones in his report) at four inches distance.

At about this same distance he could distinguish the marks on the face of the chronometer. He used a lamp when calling the time by it.

Mr. Thompson read the fine print of which he has given a specimen at the distance of four inches; about half of that at which he usually reads; found it easier to read in the midnight twilight in the harbor. (See his report.)

Mr. Nones noticed the distances at which he read the two specimens attached to his report as being ten and six inches, respectively. Purser's Steward Collins could but just discern from the steamer's deck the black tops of the mountains which surrounded him.

(16.) *The corona; its peculiarities as to exterior outline, eccentricity, &c.*—As already stated in the extract from the report of Dr. Barnard, nine-tenths of the sky was covered with clouds; in consequence of this only one of the astronomers (Lieut. Ashe) caught a glimpse of any portion of the corona.

Lieut. Ashe says that "at 2*h*. 5*m*. 32*s*., (9*h*. 13*m*. 33.2*s*., mean time,) the last spot of light vanished, and a bright halo surrounded that part of the moon that I was looking at; and at about 20° in the second quadrant I saw a white flame shooting up to a considerable distance." His standard of reference was the vertical. (See his sketch or figure 6, of Sketch No. 39.) He used no screen glass in observing the total immersion.

"A dense cloud now passed over the sun, and prevented any further observation being made until the emersion."

Yet through an opening made in the clouds the corona was seen on shipboard by the seamen at a position about three-quarters of a mile to the SW. of our station.*

The report of Purser's Steward Collins states that "the size of the ring appeared to be about one-third as broad as the dark moon, and of a bright radiant color, emitting quivering and sparkling beams of light, but uneven in its size and intensity all around."

A drawing was made with the attempt to justify this description. The same was corrected under the immediate inspection of Mr. Collins, who was very specific in his statements and corrections. He then showed it to those who had witnessed the phenomenon, and they insisted upon one or two amendments, with respect to which he was uncertain, and it was then pronounced to be a very exact picture of what they remembered to have seen.

I consider it therefore to be a reliable representation of the appearance, as viewed without a telescope;† and all the rather because the beam marked B, in the reduced copy, (Fig. 6, Sketch No. 39,) has the position (for direct vision) in which Lieut. Ashe saw the white flame shooting up; and the eccentricity of the corona is manifested in the very direction in which it might have been anticipated, (if seen at all,) as we were in all probability somewhat to the south of the path of the central eclipse.

(17.) *Stars seen during the total immersion; also their color.*—Lieut. Ashe saw Capella shining brightly, but cannot aver that its color was red.

Acting Sailing-Master Platt still continued to see Capella at about 9*h*. 20*m*., or 3½ minutes after the first emersion of the sun's beams from the total eclipse.

Mr. Thompson saw Capella shining with a bright *white* light.

The report of the seamen speaks of four stars, one (which seems to have had the position of Venus) they all describe as appearing yellowish.

M. Duchochois saw Castor, Pollux, Capella, Venus, and Jupiter. Capella appeared *white.*

(17 *bis.*) The proposed search for the intra-mercurial planet could not be conducted because of the clouds; nor could I examine the peculiar illumination of the planet Venus, as I had myself intended.

* About as far on the other side of us, where I had stationed another observer to notice some of the phenomena, nothing could be seen, as he was in a shower of rain.

† In this view several of my colleagues agree with me who witnessed the clearness and precision of the statements of Mr. Collins, and the character of his corrections.

Lieut. Comg. Murray saw a bright star in the comet-seeker immediately after the sun had vanished; position uncertain. (Venus?)

(18.) *Force of the wind and character and direction of the clouds, especially during the total eclipse.*—An extract from Mr. Lieber's meteorological report exhibits:

Time.		Wind, force of.	Clouds, &c.
h.	*m.*		
8	13	W. by S. 7	Clouds cumulus; fog on mountains
8	16	W. by S. 5	Clouds 8 cumulus; fog on mountains.
8	20	W. by S. 7	Do. do.
8	22	W. by S	Clouds as before; rain coming from W.
8	23	SW. 7	Shadows of clouds now appear and from eclipse.
8	26	SW. 4-5	
8	29	W. by S. 7-8	$8\frac{1}{2}$ stratus N.; nimbus E. and W.
8	33	NW. 6-8	Clouds 8; rain just north.
8	34	NW. 9	
8	36	NW. 6-8 (gusts)	Do. do.
8	40	NW. 5	Clouds 8; open in spaces over sky.
8	45	NW. 4	Clouds $7\frac{1}{2}$; thin on horizon, especially to the N.
8	50	NW. 4	Clouds $7\frac{1}{2}$; sun not fully visible.
9	06	NW. 3-4	Do. do.
9	12	NW	Sky very blue for here.
9	15	W. 3	Sky very gloomy; clouds to east purple; lightening again.
9	16	W	
9	17	W. 3	Same; much lighter.
9	22	W	Much lighter.
9	25	W. 5	Nimbus clouds, with thin haze.
9	31	W. $\frac{1}{4}$ S. 3	Over sky (6): nimbus on high mountains to west.
9	36	SW. 4	
9	45	W. 3	Clouds 6; cumulus and nimbus.
9	49	W. 3	Clouds 5; cumulus moving with wind.
9	55	W. 3	Do. do.
10	00	W. 3	Clearing; thick fog in south.
10	16	S SW. 2	Clouds 7; thin rain.

The wind was fresh for some time before the eclipse, and all the observers near our station agree in saying that the wind moderated and had arrived nearly at a lull at the time of greatest obscuration, in the midst of which a very sudden gust arose and almost as quickly ceased. (See the several appended reports of Mr. Thompson, Mr. Platt, and the seamen.)

Chief Engineer French, however, who, at my request, observed on an eminence, found the wind invariably light and from the northwest. He was much more enveloped in clouds than ourselves, and could not trace the other phenomena.

(19.) *Effect on the temperature.*—An inspection of the meteorological report hereto appended will show that there was little or no change of temperature during the eclipse. This has also been, in other instances, true, when the sun was not eclipsed, though our experience at our station has been limited. When a change did occur within the same hours of the day, the range amounted to from five to eight degrees. The *rise* of the thermometer may have been prevented on this occasion.

From the observations of the quartermaster it appears that the thermometer, on ship-board, fell seven degrees and afterwards rose five degrees.

(20.) *Polarization of the atmosphere.*—Several observations of this phenomenon will be found detailed in the report of Professor Venable, who used Savart's polariscope. His closing remark is, "I do not think that any conclusions can be drawn from these observations, as to any effect of the eclipse on the polarization of the atmosphere, though no observations were made, in this respect, during the total eclipse."

The like conclusion has been drawn by Mr. Lieber from the observations specified in his report, though the intensity in the direction south seemed to be increased about the time of the total eclipse. The view was at all times more obstructed there than that in an opposite direction. Mr. Lieber used Arago's polariscope.

(21.) *Electrical phenomena.*—Peltier's apparatus never gave any indications, though frequently tried on various occasions by several observers.

(22.) *Photographic impressions of the sun when eclipsed and when not eclipsed.*—The perfection and importance of these has already been alluded to, as well as some of the phenomena which they represent. The report of Mr. Duchochois and Mr. Thompson exhibits particulars with regard to times, &c., at which the impressions were taken, and is, withal, specific with respect to all the arrangements, as well as the preparation of the plates.

(23.) *Effects on animals.*—Six ducks which were on shipboard were observed to put their heads under their wings and otherwise arrange themselves for sleep as at the approach of night.

But a bird of a species not recognized by us, of great sweetness of song, was distinctly heard at 9*h.* 6*m.* and 9*h.* 11*m.* 15*s.*, and again about two minutes later, when the sun was totally eclipsed.

The record of observations of Lieut. Comg. Murray is drawn from his notes, made at the time. Copies of the reports of other officers of the steamer, and that of Purser's Steward Collins, which is a synopsis of what the seamen observed, will all be found in their proper places.

Meteorological observations.—These have been systematically conducted under the immediate supervision of Prof. Venable, and have been maintained during both the voyages outward and and homeward, as well as the stations at which we stopped. The observations were made by Prof. Venable, Mr. Lieber, and Mr. Henry, a distribution of labor having been made by them in accordance with rules agreed upon among themselves, subordinate to the directions furnished by Prof. Henry; and they have had occasional aid from some of the officers of the steamer. A copy of their report in full is annexed.

Magnetic observations.—Appended also is a copy of an abstract of the report of Mr. Goodfellow, of the observations of himself and Mr. Walker, in which special reference is made to the effect of the eclipse.

The magnetic observations were made in accordance with your own special instructions, and the report is therefore to yourself direct; and in like manner they will report in full.

Reports or abstracts from them were called for while the phenomena were yet fresh in the recollection of the observers, and a brief synopsis of the observations and some of their results was inserted in a bottle and buried near the tide station under a cairn, in accordance with the plan heretofore made known to you. The paper was signed by myself in character of astronomer in charge of the expedition, and countersigned by Lieut. Comg. Murray, who also made a similar deposit, under the same cairn, of a chart of the harbor.

My own account contained a statement of the reasons why the bottle was deposited, and Lieut. Comg. Murray gave directions to the finder of the bottles as to the disposal of their contents.

It remains but that I should acknowledge on my own behalf and that of my associates our special obligations to Lieut. Comg. Murray for his hearty co-operation in our observations and all that could promote them, his persevering kindness in promoting, in other respects, our comfort and convenience, and our sense of obligation for his prudence and forethought in the midst of a navigation and of weather sometimes eminently hazardous.

We would also speak in terms of high commendation of the skill, zeal, and devotion, within his own sphere, of Acting Sailing-Master Platt, especially under the circumstances to which we have already adverted; also of the aid we have derived from the ingenuity and skill of the chief engineer, Mr. French, and of the ready co-operation of the other officers, whose observations, and even those of the seamen, we have found to be valuable.

I am, sir, very respectfully, your obedient servant,

STEPHEN ALEXANDER.

NEWPORT, *Rhode Island*, *August* 7, 1860.

Observations on the total eclipse of the sun of July 18, 1860, *made at the camp of the Labrador expedition, Aulezavik island, by F. A. P. Barnard.*

My observations were made by the aid of a 45-inch telescope, of three inches aperture, constructed by Utzschneider and Fraunhöfer, belonging to Columbia College, New York.

In accordance with my instructions, I looked most carefully for any evidence of the approach of the moon's limb to the sun before the actual contact, varying my darkening glasses for the purpose.

I could discover no trace of the border of the moon until her actual encroachment upon the sun's bright disc made it manifest. I am satisfied, however, that this negative result is no sufficient evidence that, with different arrangements, the limb might not be earlier visible. With slightly colored glasses, the radiance of the sun itself dazzles the eye; and with shades sufficiently deep to subdue this brightness, a conclusive observation on this point appears to be impossible. A telescope, with an opaque disc at the focus just large enough to intercept the sun's light, might allow observation without a shade; and, with such an arrangement, it is not impossible that the limb of the moon might be seen projected on the supposed atmospheric envelope of the sun.

First contact of limbs.—The moment I was absolutely certain of a contact between the two bodies I noted the time, which, by the standard chronometer,* was 1*h.* 0*m.* 11*s.* I ought to observe, however, that I perceived the contact before I was sure enough of its reality to make a note of it; and, according to my judgment, about 3*s.* had elapsed after I suspected it before I was sure of it.

The effect of unequal refraction, in giving a wavy outline to the entire disc of the sun, contributed to this uncertainty.

Spots, immersion, &c.—As the eclipse advanced, clouds continually drifting over the sun very much interrupted observation.

I had prepared in advance a map of the spots on the solar disc, made without instrumental measurement, but sufficiently exact to serve as a guide in the observation of their immersions and emersions. Only three immersions, however, were observable by me, and these occurred in a group of spots near to the centre of the sun, at the times, by standard chronometer, as follows:

1st	1*h.*	53*m.*	29*s.*
2d	1*h.*	53*m.*	52*s.*
3d	1*h.*	54*m.*	7*s.*

Emersion of spots.—The emersions of the spots were more generally observable than the immersions. Still, it was not possible to secure all; and some which, perhaps, might have been secured, I lost by having my attention directed at the time to other parts of the moon's limb. A very large spot or group of spots in the northwest quadrant (southeast in the telescope) was first recognized at 2*h.* 21*m.* 43*s.*, and its last border came into view at 2*h.* 22*m.* 25*s.* Other spots appeared as follows:

2*h.* 29*m.* 7*s.*	2*h.* 58*m.* 47*s.*	3*h.* 2*m.* 47*s.*
2*h.* 51*m.* 22*s.*	3*h.* 0*m.* 12*s.*	

Total immersion and emersion of the sun.—The total immersion of the sun occurred at 2*h.* 5*m.* 28*s.* It was observed through a veil of clouds not sufficiently dense to cut off the direct rays of the sun, but quite enough so to render any subsequent phenomena invisible until after the emersion had taken place.

Fading of the sunlight.—The eclipse had not far advanced before the diminished brightness of the solar light became very obvious. Except for the floating clouds, the atmosphere was

* Bond & Son, 177, is here referred to, and in the other reports of the astronomers.

clear, and before the eclipse began we had the cheerful and vigorous brightness of a summer day. From this, the first marked appearance of change was the waning of this brilliancy into something like the feeble and ineffectual radiance so noticeable occasionally in the winter days of New England. After this the daylight took on a more lurid character; the landscape appeared dull and cheerless; yet I could not perceive any change in the tints of the objects near at hand. The sky was very beautiful. At *1h. 30m.* I was very much struck with the intense blue of the sky immediately overhead, and also in the intervals of the clouds in the vicinity of the sun. The clouds themselves being fleecy and thin, presented a vast variety of fantastic forms of the intensest and purest white; and these, by their strong contrast, brought out the deep tint of the sky more strikingly.

At the hour just named the clouds covered about nine-tenths of the heavens. At *2h.*, just before the total immersion, I once more noticed the tint of the uncovered sky, and found its darkness greatly increased. It was still purely blue, but with a depth of azure almost equal to that of the ocean.

Appearances during total obscuration.—The last direct ray of the sun having been cut off while that body was too deeply enshrouded in clouds to be visible, I withdrew my eye from the telescope with a feeling of deep disappointment, and gave my attention to surrounding things. The darkness was not such as to incommode me in performing any ordinary work. I looked up the bay, towards the north, and could have distinguished persons or boats at a great distance. After looking all about me, I took up my note-book and wrote these lines:

"During the total obscuration the horizon presented the appearance of twilight; in the north, especially, it was red.

"Countenances were not ghastly.

"Could read and write with pencil with facility."

Presently after, perceiving that Mr. Henry was availing himself of the assistance of a lamp to observe the chronometer, I took up my book again and read my pencil notes, in order that I might be quite sure of the correctness of my statement. I found no difficulty whatever in reading them in any position.

The redness of the horizon was remarkable in the north, chiefly, perhaps, because the north was the only point of the compass which furnished a horizon down to the sea. Looking in that direction, the appearance presented was very like what we observe here nightly at about 11 o'clock. It is, however, to be remarked that the obscuration of the greater part of the heavens, and particularly of the region of the sun, by clouds, contributed to the remarkable resemblance between this light and twilight. In the northern horizon there happened to be a few clouds.

But while the aspect of the lower heavens had so strong a similarity to the ordinary appearances of twilight, it cannot be said that the general aspect of nature, or the kind of illumination that prevailed, was devoid of a certain singularity which it is difficult to describe, and which I have never witnessed under other circumstances. It was on this account that, remembering the statements which have been made of the funereal gloom and death-like pallor observed in similar moments before, I looked carefully into the faces of those who were nearest to me, in order to detect, if possible, any such traces there.

The result of this observation I recorded at the time in the brief note above quoted. I perceived no such change in any of the countenances about me.

Appearance of the moon's limb during the partial eclipse.—The outline of the moon, as projected on the sun, was by no means regular. The most remarkable irregularities were observed on the (apparent) upper portion of the outline. As the crescent grew narrower these irregularities became more noticeable, in contrast with the clear, well-defined outline of the sun's adjacent border.

Breaking up of the crescent before total obscuration.—When the bright crescent of the sun

remaining uneclipsed had been reduced to an exceedingly narrow line of light, it broke up into several portions. The phenomenon was so quickly over that I had not time to count them. These were more towards the upper cusp (the actual south cusp) than towards the other extremity. I saw no long black lines seeming to divide or cross the crescent, while the breadth still remained sufficient to mark them as lines.

Had I never heard or read any discussion of this phenomenon I should have inferred that the breaking up was owing simply to the irregularities of the moon's limb, which already had been so distinctly seen, rendered more striking in the impression produced by them by the effect of irradiation dilating the still unobscured portions of the sun's edge up to the latest moment.

Final contact.—The final contact of the two limbs was observed by me at 3*h.* 17*m.* 2*s.* time of the standard (Bond) chronometer. I watched, after the contact, for any remaining trace of the moon's margin, but could observe none.

I at no time saw any of the lunar spots, or any appearance indicative of the presence of the body, except its effect in cutting off the light of the sun.

Owing to the interposition of clouds during the entire period of total obscuration, the matters on which I had been most especially charged to observe and report—viz: the appearance of the corona; its dimensions; the red or violet clouds usually seen in it; their positions, forms, growth, or diminution; and other analogous matters—were altogether unobservable.

Respectfully, &c.,

F. A. P. BARNARD.

Report of Lieut. E. D. Ashe, R. N., director of the observatory, Quebec, on the solar eclipse of July 18, 1860, *at Aulezavik, Labrador.*

Wind from NW., blowing in gusts; large masses of clouds passing from the NW., with clear openings.

My telescope was by Dolland, of 42 inches focus, with an aperture of 3½ inches; the power was about 40, and the color of the shade was light orange. It was mounted upon a tripod, having a rack and pinion motion, and was so placed that by only moving it in right angles I could keep the object in the centre of the field.

I was comfortably seated, and was intently looking at the point of contact, when, at 1*h.* 0*m.* 56*s.*,* the dark edge of the moon was seen upon the sun's surface. I must confess that, nothwithstanding that I had promised to keep myself quite calm and collected, I was so startled by the phenomenon that I am doubtful of the time to two seconds.

There did not appear to be any disturbance of the sun's limb before contact, and the moon's limb also approached the spots in the sun without any attraction or repulsion. The time of passing several was noted with accuracy.

About eight minutes before the total eclipse I removed the colored screen from the eyepiece, and as there was a light thin cloud over the sun, I could look steadily on the bright part without protection to the eye. At this time I looked around upon several objects that were before brightly illuminated by the sun; but now a great change had taken place. A gloomy, unearthly light fell upon all objects, impressing me with the idea that some fearful calamity was about to happen; and I can well imagine that armies engaged in deadly strife would lay down their arms when nature cast so ghastly a light upon the battle field.

When the bright crescent was reduced to a thin line of light, it was a beautiful object to behold, extending about 130 degrees around the edge of the moon. Shortly afterwards it broke

* Probably 6*s*, instead of 56*s*.

up into fragments, which appeared to swim from the centre towards the cusps. At 2*h*. 5*m*. 32*s*. the last speck of light vanished, and a bright halo surrounded the part of the moon that I was looking at, and at about 20 degrees in the second quadrant I saw a white flame shooting up to a considerable distance.

A dense cloud now passed over the sky and sun, and prevented any further observations being made until the emersion, the time of which was noted at 2*h*. 8*m*. 39*s*.

At the time of the total eclipse, the wind, which had been blowing in gusts, now fell, and a death-like stillness prevailed. A little solitary bird poured forth a melancholy song, and then the stillness appeared even greater than before.

Between the clouds I saw Capella shining brightly with her natural light.

The darkness was not so great as I imagined it would be; I could see the remarks in my note-book without much difficulty. The light is totally different from that of morning or evening.

The cusps were well defined, both during the immersion and emersion, except at 2*h*. 25*m*. 54*s*., when the lower cusp appeared to be broken off, instead of coming to a point. I could follow the edge of the moon off the sun three or four degrees.

The faculæ on the sun's surface, around the edge of the moon, at the last part of the emersion, were very distinctly seen, (Figure 7, sketch No. 39.) Two high mountains in the moon were seen at the immersion, just under the upper cusp.

I have spoken of the phenomena as seen through an inverting telescope, and a vertical and horizontal line supposed to be drawn on the surface of the sun.

	h.	*m.*	*s.*
First contact	1	00	56*
A, by 1st limb		54	09
B, by 2d limb		54	32
Total eclipse	2	5	32
C, by 2d limb, (centre)		21	52
D, flattening of lower cusp		25	50
Last contact	3	17	01
F, emersion	2	8	39
E, white flame.			
f, halo.			

Report of Prof. A. W. Smith—eclipse of July 18, 1860.

ECLIPSE STATION, *Aulezavik island*, *July* 20, 1860.

SIR: I herewith submit a report of the observations made by myself during the solar eclipse of the 18th instant at our station on the coast of Labrador.

The telescope used by me belongs to the United States Naval Academy at Annapolis, Md., and was loaned to Prof. Bache for the purposes of the expedition. From this circumstance, I suppose, it was assigned to myself on this occasion. It was made by Plössl, of Vienna; has an object glass of about three inches aperture and thirty-eight inches focal distance. There were eight eye-pieces, one with a position micrometer, which, however, was out of order. After trying the different powers upon the sun the day before, I decided to use the lowest, in order to bring the whole disc of the sun into the field at once. The telescope is equatorially mounted, and was roughly adjusted, so as to keep the sun in the field during the eclipse while clamped in declination. I found, however, while observing the eclipse, a perceptible want of achromatism on the borders of the field, and the tangent screw being too fine to enable me

* Probably 6*s*, instead of 56*s*.

to bring all parts of the sun's disc into the centre of the field with the needful despatch, I unclamped the declination circle.

The screen used at every recorded observation gave a white image of the sun. At your suggestion, I used an angular eye-piece, which I found generally much more convenient, as the instrument was placed quite low; but the use of this eye-piece made it much more difficult to recover the sun, when, during concealment by a cloud, it passed out of the field, or was thrown out by accident, which was the case in one or two instances.

1. The first contact of the moon with the sun was observed at 1*h.* 0*m.* 14.5*s.*, but the indentation, when first detected, was so large as to indicate that actual contact occurred some seconds earlier. I could not discover the moon before contact, though I scrutinized intently for it.

2. A bright but narrow band of deep yellow was seen soon after the moon's limb entered upon the sun's disc, and was visible, or was seen, till the moon approached the large dark spot on the sun. It may have continued longer visible, but my attention was not subsequently directed to it. This was not the effect of chromatic aberration, as the whole band was made to pass near the centre of the field, and was separated from the white light of the sun by a distinctly seen dark line.

3. Contact of moon's limb with the penumbra of the large spot, about 1*h.* 12*m.* 35*s.*, but vision was indistinct on account of a cloud.

4. At 1*h.* 52*m.* noticed the lower cusp slightly distorted or curved inwards towards the moon.

5. At 1*h.* 53*m.* 33*s.* contact with small spot in the (apparent) SW. quadrant, (actual SE.) At 1*h.* 53*m.* 47*s.* spot totally obscured; at 1*h.* 53*m.* 57*s.* contact with a second small spot; at 1*h.* 54*m.* 4*s.* contact with lower one of the group.

6. At 1*h.* 57*m.* the concavity of the lower portion of the crescent appeared irregular. It was indented in two places, and at 1*h.* 58*m.* another indentation was discovered still further up, the latter being about twice as far from the extremity of the cusp as the second of the preceding ones. At this time a bird was heard to sing.

7. At 2*h.* 1*m.* a narrow red line or band was seen skirting the moon's border and apparently on the moon's surface. At 2*h.* 4*m.*, (I find an entry was made on my note-book, under this date, simply of "blue flashes," but I am unable to recall or locate them.)

8. At 2*h.* 4*m.* 41*s.* dark lines appeared, dividing the upper portion of the fine silvery line of the sun's disc, giving to it a fragmentary appearance; the lower portion was indistinct, being partially concealed by a cloud.

9. The last recognition of any portion of the sun's disc was at 2*h.* 5*m.* 27*s.* Whether the disappearance was that of total obscuration or was occasioned by the increased density of the intervening cloud I could not decide.

10. The emersion was not seen, either because of the cloud or because the image was thrown out of the field, and, using an angular eye-piece, I was not able to recover it in time.

11. The large spot was not seen till 2*h.* 21*m.* 51*s.* At 2*h.* 25*m.* 55*s.* the upper cusp appeared cut off or rounded.

12. At 2*h.* 28*m.* 16*s.* the moon presented, more distinctly than at any other time before, the appearance of a hemisphere and the definition of all portions of the phenomenon more perfect, as if seen through the most perfectly transparent atmosphere. At this time a blue band of considerable breadth surrounded that portion of the moon which covered the sun. This band appeared to be made of radiations of blue light of different degrees of intensity in a direction perpendicular to the sun's surface. It was bounded by a well-defined line on the moon's surface. I was instantly reminded of the "mirage," so frequently witnessed on our voyage to this place, in which the horizon appeared to be skirted by a blue sea-wall. The resemblance to an unbroken sheet of water (varying in thickness or irregular in surface, so as to vary the

shading) falling over a mill-dam also occurred to me. At the base, where it was in contact with the sun, was a very narrow band or line of yellow light, as noted in No. 2.

13. At 2*h*. 32*m*. the upper cusp appeared bifurcated, one of the divisions being prolonged beyond the other.

14. At 2*h*. 35*m*. 43*s*. a bluish light was seen to flash around the lower limb of the moon from the sun's disc, having a curvature the same as that of the moon, seeming, for the moment, to reveal the border of the moon beyond the sun's disc.

15. At 2*h*. 55*m*. flashes of yellow light appeared to stream up from the moon on to the sun; subsequently they were perceived to be faculæ on the sun's disc.

16. At 3*h*. 1*m*. another spot appeared.

17. The last appearance of the moon's limb was at 3*h*. 17*m*. 1*s*. It was probably concealed from view by a cloud, and passing out of the field I was not, from the character of the instrument and the circumstance that it was not in accurate adjustment, able to recover it before the end.

Of the phenomena specified in the list, to which my attention was specifically called by you, I have referred in the foregoing, with one exception, to those only which were actually seen. During the entire period of the eclipse I did not, more than once or twice, turn my eyes in the actual direction of the sun, being anxious that nothing which the telescope might reveal should escape me, and therefore can report nothing of the general appearances to unassisted vision.

I regret that I have not the means at hand of illustrating by diagrams some of the foregoing observations, especially those attended by color.

Respectfully submitted.

Your obedient servant,

AUG. W. SMITH.

Prof. S. ALEXANDER,
In charge of U. S. astronomical expedition.

Report of Prof. C. S. Venable on the total eclipse of July 18, 1860.

At 1*h*. 0*m*. 15*s*. saw the first contact, the moon's rough edge just on the edge of the sun. At 7*m*. 9*s*. observed some distortion of the upper cusp. The observations were made with a screen of green glass. At this time, and several times during the observations, I thought the portion of the sun around the moon's edge brighter than the rest, but could not, with my telescope, distinguish it as a *bright band* around the moon's edge.

At 13*m*. 27*s*. saw the large spot (marked in the diagram) submerged without any peculiar appearance. I now devoted a short interval to the observation of the polarization of the atmosphere, the results of which I have stated below.

At 41*m*. noticed the rapid darkening of the landscape, and the beautiful tints of the cloud shadows on the mountains on the opposite side of the bay. At 51*m*. again observed a distortion of the upper cusp.

The lower of the two spots of second magnitude marked on the diagram began to be submerged at 53*m*. 19*s*. and the upper one at 53*m*. 57*s*., without any accompanying and peculiar phenomenon. At 54*m*. 24*s*. the upper one entirely covered. At 56*m*. 5*s*. noticed the edge of the moon rougher at the upper cusp. At 59*m*. the blue-green tints of the cloud shadows and of the mountains very beautiful.

At —*m*. 58*s*. the distortion of the upper cusp much greater, and at 59*m*. 17*s*. observed the formation of a bead at the upper cusp; saw two or three form. The clouds now interfered to such an extent that it was only at intervals that I could catch glimpses of the decreasing

crescent, and I made no observation of the peculiar phenomena which could be relied on. Just before the total eclipse I looked up from the telescope in despair at the sky, and saw the last drop of the crescent flashing and twinkling like a bright and beautiful star through an opening in the clouds, then suddenly extinguished at 2*h.* 5*m.* 29*s.*

At 7*m.* 58*s.* could read the advertisement print of an ordinary newspaper at four inches distance, or, to speak more accurately, I was compelled to bring my eyes much closer to the paper to read it than on ordinary occasions.

Observed the reappearance of the large spot at 2*h.* 21*m.* 53*s.* Saw a bluntness of the upper cusp at 25*m.* 50*s.*

About this time observed, with green glasses, the two long bright lines across the sun's disc, which appeared to come from the moon's border. They were very bright faculæ. I observed the time of last contact to be 3*h.* 17*m.* 1*s.* I did not fix the position (by the lines) of the first contact, but by recollection I make it a little more than 45° from the vertex. I estimated the position of the last contact at about 48°, or 50° from the opposite vertex.

With regard to what was specially assigned to me in your programme, viz: the corona and roseate clouds, I have to state that the clouds prevented all observation of them.

The positions of the spots before the eclipse were determined both by Prof. Barnard and myself.

At frequent intervals during the eclipse I made observations on the polarization of the atmosphere with Savart's polariscope. At 1*h.* 19*m.* hardly any perceptible polarization within 30° of the sun. Maximum was near the horizon, between N. and NE.; also very strong in SW. At 1*h.* 34*m.* no material change; stronger, perhaps, in NW., commencing above the horizon, at about 35 or 40 degrees from the sun. At 56*m.* max., in east. At 2*h.* 14*s.* noticed a diminution of polarization in SW. In NW. strong, and in N. and NE. same as at first observation. At 2*h.* 31*m.* polarization max. in NW. and NE. I do not think that any conclusion can be drawn from these observations as to any effect of the eclipse on the polarization of the atmosphere, though no observations were made in this respect during the total eclipse, as I was anxiously looking each instant for the clouds to pass over so that I could observe the corona and the accompanying phenomena.

On the afternoon of the 18th, in connection with Dr. Barnard and Mr. Lieber, I made the simultaneous barometric observations for the determination of the height of our station above the sea level, as well as of two of the peaks of the mountain chain at whose base we were anchored. From these observations I ascertained the height of the station to be 110 feet, and of the peaks to be, respectively, 1,729 and 2,150 feet above the level of the sea. For the highest of these peaks, which is on the northern point of Aulezavik island, overlooking the sea and the harbor (Sketch 38) in which the vessel was anchored, I have the honor, in connection with Com. Murray and Mr. Lieber, to propose the name of Mount Bache.

C. S. VENABLE.

[Extracts from the detailed report of Prof. Venable.]

"*Earth temperatures*, (*Aulezavik.*)

"In boring the earth for the burial of the bottles of water according to instructions, I could not get the depths therein required. At a depth of three or four feet I either met with rocks which required the pickaxe, or a soft caving mud. I buried three bottles, which gave the following temperatures:

"Depth two feet, (wet,) temperature 40°.

"Depth two and a half feet, (wet,) temperature 40°.

"Depth three feet, (dryer,) temperature 43°.9.

"These holes were bored around the meteorological station, 110 feet above the sea level.

"I tested the temperature of nine springs which had their source doubtless in the winter's snows. There was very little snow to be seen on the mountain side from which they sprung. They had different elevations, varying from 500 to 100 feet above the sea level. The following temperatures were obtained: 39°, 35°, 35½°, 37°, 39°, 40°, 41°, 37¾°. One pond gave 46°, and two small streams at a short distance from their sources gave 45° each."

"*Atmospheric electricity.*

"For these observations, through the kindness and skill of Mr. French, chief engineer of the Bibb, an instrument was made by which I was enabled to elevate the ball to a height of twenty-two feet above the earth's surface. This was done by means of a pole running in a long groove, and elevated by a small pulley. I made repeated trials with the apparatus, using both the small reel with the covered wire, and subsequently the lever insulator, with wire and handle, but obtained no indications of electric action. The weather was not at any time very favorable, due to the winds and moisture. The experiments were made repeatedly on different days by myself alone, and then with Prof. Barnard, and subsequently by Mr. W. A. Henry, when the electrometers exhibited a very considerable degree of sensitiveness, and still there were no perceptible indications of electricity on application of the ball."

"*Icebergs, snow, &c.*

"On July 6, in the morning, saw first small iceberg, and small masses of broken ice floating about. Saw first snow on the mountains of Labrador. This was in the straits of Belle Isle. From this point to Aulezavik icebergs were constantly in view, and snow in patches along the whole line of coast mountains, in many places down to the water's edge. I record below several notes made on different days.

"July 7, 8.30 p. m., thirty-four icebergs in sight, varying from thirty to two or three hundred feet in height, and from fifty to two or three hundred feet in length.

"July 12, 7½ p. m., ten icebergs in view; very large. The estimates of their magnitude very various. Off Port Manvers the most massive one was seen, six or seven hundred feet long, and one hundred to one hundred and fifty feet high. Much higher estimates than this were made by many. I had one or two opportunities of experimenting on these large icebergs with the minimum radiation thermometers. They produced no effect at a distance of several hundred yards. From the top of Mount Bache, at the head of Aulezavik harbor, Mr. Lieber and I saw thirty-six icebergs to the south and east of the mountain, and to the northeast a field of ice many miles in extent. I observed the same field the day afterwards from one of the mountains on the main land on the opposite side of the harbor. The advance guard of this ice field consisting of hundreds of comparatively small lumps projecting fifteen or twenty feet above the surface of the ocean. On the return voyage there were still a great many icebergs visible. Many, however, had disappeared, broken to pieces most probably by the gale of the 22d and 23d of July. There was much more floating ice than on the upward voyage. There were several slight showers of snow and hail at Aulezavik, as reported in the journal, besides the storm of the 22d. Some few flakes fell on the mountain top on the evening of the 18th, and in the gale of the 22d and 23d the mountains were covered down to the water's edge. We had no opportunity of testing its depth, as we were very effectually confined on shipboard. This newly fallen snow was visible between two and three hundred miles south of Aulezavik, on the sides of the coast mountains.

"On an island off the coast, near the harbor of *Nain*, Mr. Lieber found a specimen of red snow, which was examined by Prof. Barnard with the microscope. The red spores of the *fungus* were very prettily exhibited. Another specimen of this snow was found by Prof. Barnard on the mainland north of Aulezavik harbor.

"*Mirage and other phenomena.*

"There were many instances of mirage during the voyage. Inversions of vessels in the offing changing contour and elevation of coast lines. In my notes I have remarked one or two of these days.

"July 1, off Halifax; vessel inverted in the horizon.

"July 7; a day of grand mirage. Coast lines varying fantastically each moment. Icebergs lifted in the clouds and inverted. In one case an iceberg seen on three levels. Cannot speak positively of any evidence of lateral refraction.

"July 8; continuation of same. Tops of icebergs lengthened and pointed. One image of iceberg seen for nearly half an hour suspended in stratum of clouds which skirted the horizon, the base being far above the horizon.

"*Rainbow.*

"On the top of the peak above the meteorological camp were seen by Mr. Lieber and myself three rainbows, as represented in Figure 8, (of Sketch No. 39.) First, the ordinary bow; then one concentric with this, and having the colors of the *spectrum* arranged similarly with the first. The mountain side prevented a second contact or cutting of these two bows. Concentric with the first came the ordinary secondary bow, with the colors in inverted order. All of these were very bright, the second one not so bright as the other two.

"*Auroras.*

"Saturday, June 30: aurora, first appearance 8.45 p. m., and continued several hours; base of arch extended from *Gemini*, in west, about 120°, having vertex nearly under Polaris. At 11 p. m. sent streamers up to zenith over Arcturus on one side, and *α* Aquilæ on the other. The arch was of pale sulphur color, the streamers varying to bright red.

"Sunday, July 1: auroral arch of nearly the same dimensions—not so distinctly defined sent rays nearly to zenith. Arch of pale sulphur color. Rays varying at times to bright red.

"Monday, July 2: aurora observed at 8 p. m.; continued with various changes to 12 p. m. or later. Arch of nearly the same positions and dimensions as the preceding, but not entirely filled out nor so distinctly defined. Rays on both sides of centre, and immediately through the centre of arch to zenith. Rays varying in color from pale sulphur color to bright red.

"Wednesday, July 4: aurora observed at 9½ p. m. Vertex of arch 70° from horizon—formed in south. Beams having a dome-like structure. Arch dense, and of sulphur color. Partial corona formed two or three times; most imposing at 11 o'clock. Red rays very beautifully intermingled with the pale yellow at different times, and giving, as in the other auroras, more distinct polarization. Most beautiful beams in the northeast.

"July 8: aurora observed at 11 o'clock. Streamed up from NW., between Arcturus and tail of Ursa Major, flowing up, as it seemed, in the constant continuous vibrations of bright waving changing colors, varying from pale straw color through deep sulphur and bright red. These irregular beams streamed up beyond zenith, circled around *α* Lyræ down so far as *α* Aquilæ, including in its feathery, flowing curtain-like folds Ursæ Minor, sometimes Cassiopeia, Cygnus, and Draco; these folds changing form and position most fitfully. At times a perfect spiral, then irregular waves. There was now and then columnar structure, and once an arch extending from NW. point under Arcturus to corresponding NE. point of horizon (SE. of const., Cassiopeia.)

"July 11: observed at 11.30 p. m. A corona formed at a quarter to twelve on the wing of Cygnus, south, beams radiating to all points of compass; corona disappeared and reappeared several times; sometimes an imperfect one, like an open fan in appearance. Bright sulphur,

yellow, and red-colored cloud beams in south at various points. Observed the phenomena until half past twelve. Once appeared in the form of two bright wings, extending from the corona point in Cygnus, nearly along the meridian, and almost to the horizon on either side, tapering gradually from zenith to horizon. The color of these almost white—strongly contrasted by dark portions in various points of the heavens. The reddish clouds showed stronger polarization than the pale. The dark portions gave the strongest polarization.

"July 12: a slight brush observed in south at 10½ p. m. A low arch formed at 11.15—vertex under Capella. Arch very pale, and indistinctly defined.

"July 16: distinct flashing of auroral beams in NE. at 8 p. m. Sun behind mountain on opposite side of bay, (Aulezavik.) These beams vibrated and flashed up nearly to the zenith. Sky very much overcast afterwards during the night.

"July 17: slight exhibition of auroral beams at 11 p. m.

"July 25: aurora reported at 12 o'clock. Arch formed in southern sky.

"July 29: aurora at half-past nine first observed. Corona half formed once or twice, giving another exhibition of the fan-like structure, and once the waving, irregular, and curtain-like form, at times assuming the appearance of the two great wings, nearly from zenith to horizon, across the meridian.

"August 1: aurora reported. Corona formed at 2 o'clock a. m.; arch-base extending from point of horizon SW. of Arcturus to point little SE. of Cassiopeia. Bright beams in the southern sky.

"August 2: aurora. A slight brush of auroral cloud at 8½ p. m.

"August 6: aurora visible from 9 o'clock p. m. until 3½ or 4 a. m. of 7th. Arch formed early—about 80° base in northern sky—vertex under Polaris 20° from horizon. Bright sulphur-colored beams varying in position visible all night, arch changed to irregular waving curtain line. At times beautifully red, especially towards zenith. At midnight, and after, very bright. At 2.20 a. m. observed the effects on prepared sulph. quin. paper—exhibited a decided phosphorescent glow."

Meteorological observations made during the hours corresponding to the eclipse at Aulezavik from July 14 to July 23.

FROM THE REPORT OF PROFESSOR VENABLE.

Time.	Barometer.	Attached therm.	Psychrometer.		Wind.		Cloud.		Ozone.	Water.
			Dry.	Wet.	Force.	Direction.	Amount.	Sort.		
1860.	*Inches.*	°	°	°						
July 14—7 a. m	29.78	78	38½	36	0	....	0	....	....	
8 a. m	....	....	40	38	0	....	0	....	....	
9 a. m	29.67	65	41	39	0	....	½	Little hazy bank on horizon	8	36°
10 a. m	29.67	65	48	46	0	....	1	....	....	
11 a. m	29.66	65	48	41	0	....	1	Fog bank on sea	....	
July 15—7 a. m	29.025	47	....	....	11	NW. by W	10	....	....	
8 a. m	29.025	47	38	37	10	NW. by W	10	....	....	
9 a. m	29.34	44	37½	36	10 & 11	NW. by W	10	Nimbus	9	
10 a. m	29.425	47½	39	36½	10 & 11	NW	9¾	Nimbus, and fog in NW	....	
11 a. m	29.44	44	40	37	11	N.	9	Nim. and cum.	....	
July 16—7 a. m	29.72	56	50	43	4	W.NW	....	Cir. cum. chiefly on horizon	....	
8 a. m	29.72	58	53½	44½	5	W.NW	2	Cir. cum. strat. chiefly on horizon	....	
9 a. m	....	....	52½	45½	5	NW	1	do	5½	
10 a. m	29.76	69	58¾	47½	5	W.NW	1	do	....	
11 a. m	29.75	69	59½	45¾	4	W.	½	Cir. strat on horizon	....	
July 17—7 a. m	29.408	37½	36	35½	9	SE	10	Fog rising; apparently clearing; motion to NW.	....	
8 a. m	29.388	41	40	38½	6	SE. by E	10	Much thinner; brightening.	....	
9 a. m	29.328	41½	37¾	36	4	S.	8	Fog; upper clouds move SW	....	
10 a. m	29 320	41½	40	39.6	3	E.	5	Fog rising; cir. cum. seen above	....	
11 a. m	29 307	43	40½	39½	2	E.NE.	8	Nimbus, ½ fog; cum. above S.	....	
July 18—7 a. m	29.421	53	45½	41	7	W.	6½	Strat. above motionless; nim. moving NW.	....	
7½ a. m	29.428	48	45½	42	7	W. by S.	8	Nimbus E. by N.; fog on mountains; polar light on mountains to N.	....	
9*h*. 6*m*. a. m	29.438	46½	45	40	3-4	NW	....	....	....	
10 a. m	29.444	48½	46½	41	3	W.	5	Cum. nim. chief in S.; clearing overhead; thick to W.; fog to S.	....	
July 19—7 a. m	....	....	50	45½	0	....	....	Clear, except few cum. and cum. strat. at horizon.	....	
8 a. m	....	....	....	....	....	....	....	....	....	
9.10 a. m	29.610	63½	51	48	1	E.	3	Nimbus; no motion	....	
10 a. m	29.522	54	52	48	2	NE.	3	Cum.; slight nim. strat	....	
11 a. m	29.522	55	50	47	2	NE.	4-5	Clouding up more and more; sun thermometer in shade.	....	
July 20—7 a. m	29.403	41	37½	36	3	N. by E.	5	Cir. cum. strat.	....	
8 a. m	....	....	....	....	3	N. by E.	....	Rain shower	....	
9 a. m	29.445	44	43	40	4	N.NE.	9	....	....	
10 a. m	29.432	44	45	40	4	N.NE.	9	Cum. strat	....	
11 a. m	29.402	46	45	40	5	N.NE.	7	Cir. strat	....	
July 21—7 a. m	29.125	50	....	....	5	SE.	9-10	Overcast	8	
8 a. m	29.10	48	....	....	1	SE.	....	Rain shower	....	
9 a. m	29.12	52	....	....	3	N.NE.	....	Overcast	....	
10 a. m	29.15	55	....	....	7	NW. by W	....	Clearing up	....	
11 a. m	29.30	69	....	....	8	NW. by W	....	Hazy	....	
July 22—7 a. m	29.20	46	....	....	1	N. by E.	10	Fog and clouds	....	
8 a. m	29 175	50	....	....	1	N. by E.	10	Fog on sea and land; 9.45, commenced raining.	8	
9 a. m	29.11	49	39	37½	2	N. by W.	10	Rain	....	
10 a. m	....	....	....	....	4	N. by W.	10	Rain	....	
11 a. m	29.11	49	....	....	4	N. by W.	10	Rain	....	
July 23—7 a. m	28.55	40	37	35	10	W.	10	Snow on land to water's edge; clouds from NW.	....	
8 a. m	29.55	44	37	35	9	W.	10	In gusts, little rain and snow, moving E. rapidly.	....	
9 a. m	28.60	52	40	36½	10	W.	9.9	In gusts; signs of breaking; moving E. rapidly.	9	
10 a. m	28.60	52	41	37	9	W.	9½	Rain and snow a little by fits.	....	
11 a. m	28.625	52	41½	37	9	W.	9	Rain ceased	....	

Meteorological observations made during the continuance of auroras observed in the Labrador eclipse expedition.

FROM THE REPORT OF PROFESSOR VENABLE.

Time.	Barometer.	Attached therm.	Psychrometer. Dry.	Psychrometer. Wet.	Wind. Force.	Wind. Direction.	Clouds. Amount.	Clouds. Sort.	Ozone.	Water.
1860.	*Inches.*	°	°	°						
June 30—7 p. m.	29.76	76	54	52	4	NW		Clear		
8 p. m.	29.71	72	53	51	4	NW		Clear		
9 p. m.	29.71	72	53	50½	4	NW		Clear		
10 p. m.	29.71	72	53	51	4	NW		Clear		
July 1—7 p. m.	29.70	74	54	51	4	W. by S.		Clear		
8 p. m.	29.72	72	51	48	4	W. by S.		Clear		
9 p. m.	29.72	72	52	49	4	W. by S.		Clear		
10 p. m.	29.72	72	52	49	4	W. by S.		Clear		
July 2—7 p. m.	29.85	63	51.9	50	3	W.	½			52°
8 p. m.	29.85	62	52	51	2	N. by W.	8	Fog bank on horizon		
9 p. m.	29.85	61	53	50	1	N.NW	1			
10 p. m.	29.85	59½	53	50	1	N.NW	0			
11 p. m.			52.5	49			2			
12 p. m.	29.85	59	53	50		N.NW	2			
July 4—8 p. m.	29.60	71	49½	47½	6	N.NW	3		8½	
9 p. m.	29.59	71	49	47	4	NW	8			
10 p. m.	29.58	70	49	47½	2	NW	8			49°
11 p. m.	29.57	70	49	47	2	NW	8			
12 p. m.	29.55	70	49	47	3	NW	9			
July 8—9 p. m.	29.80	52	42½	40½	3	S. by E.	4	Thin		
10 p. m.	29.78½	51	42½	40½	2	S. by E.	3	Hazy		
11 p. m.	29.80	54	42	40	2	E. by S.	6	Hazy		
12 p. m.	29.77	52	42	41	2	E. by S.	2	Hazy		
July 11—10 p. m.			42½	41						
11 p. m.	29.475	64	42	41						
12 p. m.	29.475	54	41	39½						
1 a. m.	29.575	51			2	SE		Clear		
July 12—9 p. m.	29.76	62	42½	40	1	NE. ½ N.	¾	Cum. strat		38½°
10 p. m.	29.76	63	42½	40						
11 p. m.	29.76	63	42	39½						
12 p. m.	29.73	55	42½	42						
1 a. m.	29.70	56	40	39	0			Calm		
July 16—6.25 p. m.	29.6[illegible]6	51	48½	42½	6	SW. by S.	8	Strat., cum cir., thin all over		
7 p. m.	29.620	48½	46½	40½	6	SW. by S.	8	Cir. cum., cir. strat., hazy, thin		
8 p. m.	29.614	49	46	41	6	S.SW	8	Cir. cum., upper moving to SE		
9 p. m.	29.520	45	44	39½	6	S.SW	7	Cum. strat., thin, steady		
10 p. m.	29.542	46½	45½	37½	2	E.NE	9	Nearly covered, nim., cum. and strat		
July 17—10 p. m.	29.420	42½	41	36½	8	NW. by W.	3	Motionless cir. cum. strat		
11 p. m.	29.338	41	41	36½	7	NW. by W.	2	Cum. cir. strat		
12 p. m.	29.334	41	41	35½	6	N.NW	2	Cir. cum. strat. No motion		
1 a. m.	29.392	42	41.5	35.5	6	NW	2	Cir. and banks of strat. seaward		
July 25—10 p. m.	29.46	58	43	42	4	SW	7	Rainy round horizon		
11 p. m.	29.48	57	43	42	4	SW	4	Clearing finely		
12 p. m.	29.50	57	43	43	4	SW.	3	Clear overhead, clouds east, stratus		
July 29—8 p. m.	29.90	62			9	W				
9 p. m.	29.90	62	44	43	9	S.SW		Clear		
10 p. m.	29.90	62			9	S.SW				
11 p. m.	29.92	58			5	S		Cloudy		
12 p. m.	29.85	54			5	S		Cloudy		
Aug. 1—0 a. m.	29.87	78	53	52	2	E	10	Thin; strat. over New Foundland		52°
3 a. m.			47½	48½						
4 a. m.	29.78	73	48	48	4	W.SW.		Fog		
Aug. 2—7 p. m.	30.23	76	62½	60	3	W. by N.	1	Clear		
8 p. m.	30.23	76	63	61	3	W. by N.	1	Hazy horizon	6	
9 p. m.	30.25	75	61	59½	3	S.SW	1	Cir. strat. in horizon		61°
10 p. m.	30.22	73	61	59	3½	S.SW	1	do.		
Aug. 6—8 p. m.	30.09	75	66	64	1	W.NW				67°

Special report of Mr. Lieber.—Observations with Arago's polariscope.

8*h*. 26*m*., polarized light chiefly north, but also a little south; none east and west.
8*h*. 29*m*., polarized light north; fading east and west.
8*h*. 40*m*., polarized light strongest north, next south; fading east and west.
8*h*. 50*m*., polarized light same as above.

Report of the photographers.

SIR: In compliance with your request, that some account of the method pursued in taking photographic impressions of the sun during the eclipse of July 18, 1860, might be given, I herewith append a short sketch of the instruments used, and the method of proceeding.

The telescope used on the occasion was of five feet focal length, mounted equatorially, and owned by L. M. Rutherford, esq., of New York, by whom it was kindly furnished to the expedition. At the eye-piece end of the telescope was firmly fixed a small camera obscura box of a size sufficient to contain a plate five and a half inches square. The camera was furnished with a side slide bearing a piece of white paper, upon which the sun's image was thrown by the "finder" attached to the telescope. The eye-piece was peculiarly fitted in order to give the very short exposure which the sun requires to impress its image upon the sensitive plate. Covering the lens was a flat brass plate, having an opening in the centre three-eights of an inch in diameter, and moved by a small spring. Upon the circumference of the plate are two smaller holes, in which a lever upon the side of the tube catches, and counteracts the action of the spring. A piece of string leading through the camera box from the outside is attached to the lever.

The method of proceeding is as follows: The plate is pushed back against the spring, and the lever set in the first of the small holes in the circumference. This holds the plate, so that the hole in the centre is just over the eye-piece; the sun's image is thus allowed to be focused upon the ground glass plate in the camera beneath. The plate is then pushed back to hole 2, and the lever inserted, thus cutting off all transmission of light through the orifice at the eye-piece. The sensitive plate is then introduced in the ordinary way. The sun's image, as shown by the "finder" upon the white paper disc, is brought by the "universal joints" to coincide with a mark made for the purpose of indicating the central position of the sun's image on the photographic plate. The string attached to the lever is then pulled; the lever is thus pushed out of the little hole, by which it holds the plate back, and the spring thus coming in play flashes across the eye-piece, and the impression is taken. The exposure is simply the time occupied by the opening in the brass plate in passing the orifice at the eye-piece, and has been estimated to be about the one-fiftieth of a second. The object glass of the telescope was adjusted for the difference between the visual and the photographic focus.

As a matter of experience connected with the successful working of the photographic preparations used in the pictures already secured it might be well to give their composition. They are as follows:

Collodion.—Sulph. ether (sp. gr. 0.72) 4 fluid drachms; alcohol (95 per ct.) 4 fluid drachms; iodide of potassium 2.5 grains; iodide of cadmium 2.5 grains; pyroxiline prepared for cadmium collodion, 5 grains.

Silver bath.—40 grains to the ounce, neutral; the nitrate of silver having been crystallized three times.

Developer.—The ordinary sulphate of protoxide of iron solution.

By these preparations the exposure of one-fiftieth of a second with a magnifying eye-piece, and a diaphragm of two inches on the telescope could have been reduced to a shorter time,

inasmuch as the latent image was developed instantaneously and with great intensity, requiring no reinforcing, and thus being a great saving of time.

Plates Nos. 6, 7, 8, 9 show a peculiar phenomenon, consisting of a bright and well marked light upon the moon's limb, gradually diffused towards the edges after the manner of a halo. This is a strong evidence of the sensitiveness of the photographic preparations, leaving no doubt that had the corona been visible a photographic impression of it could have been taken in the same time of exposure, but with the full aperture of the telescope, and without the magnifying eye-piece.

Owing to the unfortunate disadvantages of the weather but twelve pictures of the eclipse were obtained, together with three of the full sun after the phenomenon had passed. But experience proved that had the weather been fair two pictures in five minutes could have been obtained; thus securing a very complete collection of impressions showing every phase of the phenomenon.

During the total obscuration the most beautiful bluish tints were observed, certainly capable of strong photographic effects. It is to be regretted that a view of the landscape, with the splendidly tinted clouds, showing a strong contrast, could not have been taken.

As incidental information, I would remark* that during total obscuration the stars and planets Castor, Pollux, Capella, Jupiter, and Venus were observed.

P. C. DUCHOCHOIS.
A. W. THOMPSON.

NOTES BY MR. THOMPSON.—During the total obscuration a star of the first magnitude was noticed near or about the meridian, some 12 or 15 degrees south of the zenith, (Capella?) and was noticed to shine with a *bright white light.*

The accompanying fragment of newspaper was easily read at six inches from the eye about the moment of greatest obscuration. This focal distance is about half the ordinary distance of such sized print in broad daylight.

The bronze tints of clouds toward the sun, the deep yellow twilight toward the north, and the sudden gust of wind during the total eclipse were also noticed; as also the astronomical phenomenon approaching in appearance to "Baily's Beads."

A. W. THOMPSON.

Abstract of photographic operations.

ORIGINAL TIMES.					CORRECTED TIMES.				
Plate No.	h.	m.	s.		Plate No.	h.	m.	s.	
1	1	0	15.4	(Approx.)	1	8	8	17.0	(Approx.)
2	(Lost.)				2	(Lost.)			
3	1	10	31.0		3	8	18	32.6	
4	1	48	29.0		4	8	56	30.6	
5	1	53	14.3		5	9	01	15.9	
6	2	26	37.0		6	9	34	38.6	
7	2	31	34.5		7	9	39	36.1	
8	2	37	16.5		8	9	45	18.1	
9	2	48	29.3		9	9	56	30.9	
10	2	56	47.0		10	10	04	48.6	
11	3	01	55.0		11	10	09	56.6	
12	3	12	56.0		12	10	20	57.6	

* M. Duchochois here speaks.

PICTURES OF FULL SUN.	FULL SUN.
13....3h. 17m. 34.0s.	13...10h. 25m. 35.6s.
14....4 32 36.0	14...11 40 37.6
15....4 40 46.0	15...11 48 47.6

Report of Mr. R. Platt on the eclipse of July 18, 1860.

CHANGE OF LIGHT.

At first no perceptible difference.

8h.	10m.	53s.	Slight change of light.
8	13	33	Slight change of light, so as to see moon.
8	32	30	Light changing; slightly darker.
8	37		Kind of gray light; slightly dark.
8	40		Light a little more dark.
8	43		Sky appeared very blue.
8	45		Light becoming more dim.
8	47		Growing darker all the time.
8	53		Growing still darker.
8	58		Getting dark.
9	00		Growing darker
9	1		Light appears to be brown.
9	3		Light gradually turning brown.
9	8		Light becoming quite dark.
9	9		Everything becoming quite dark.
9	11		Everything looks very gloomy.
9	15		Had to light the lantern.
9	23		Quite light.

WEATHER JUST BEFORE THE ECLIPSE.

Cloudy, and fine rain; clouds moving to the eastward.

8h.	30m.	Rain ceased.
8	35	Wind blowing in squalls; cloudy, and thin fog over the mountains.
8	35.30	Rain and strong breezes.
8	40	Wind moderated a little; clouds begin to scatter.
8	48	Clouds passing to eastward, and stopped raining.
8	50	Growing darker all the time.
8	59	Growing darker a shade.
9	00	Wind moderating.
9	05	Clouds breaking a little.
9	09	Wind moderated a little, and bird singing.
9	11	Growing cold.

SHADOWS OF BODIES.

8	54	No shadows as yet, only thin clouds.
8	54	Landscape darkening.
8	58	Landscape darkening.

9*h*.	00*m*.	Landscape darkening.
9	03	Landscape appears a brown color.
9	05	Landscape turning dark brown.
9	07	Landscape fast turning dark.
9	09	Everything becoming quite dark.
9	09	Bird singing.
9	11	Can stand the light without a glass.
9	12	Getting very dark.
9	14	So dark can hardly see to write this at ten inches.

WHEN THE SUN IS ENTIRELY HIDDEN.

9	17	The wind moderated; bird sang.
9	18	Venus visible.

Capella seen 9*h*. 20*m*.

At 9*h*. 20*m*. could see the shadow advancing, and as it went over appeared like a dark column or very dark cloud.

AS THE ECLIPSE ADVANCED.

At 8*h*. 45*m*. the weather misty, and passing clouds; light getting a dark gray; the sky looking very blue.

8*h*.	55*m*.	Everything begins to look dark and gray; sky looking very blue.
9	00	Sky looking very blue.
9	02	Landscape appears brown.
9	13	Everything looks very dark and gloomy.
9	15	The shadow advancing from west, or rather the light.

R. PLATT.

Report of Mr. H. B. Nones, jr., on the total eclipse of July 18, 1860.

Approach of the shadow from the west, as seen by the darkening of the sky and landscape.—Landscape and sky began to darken when the moon had advanced a little over a third across the sun. Latter part of the shadow a dark rose color, and could be easily traced in the valley below.

Tint of sky (especially overhead) and clouds—direction of clouds.—Along the horizon the blue became gradually deeper, and overhead much darker; clouds coming from the westward, dark gray in color, and becoming deeper as the eclipse advances.

If any stars be red, or any seen, and one near the zenith.—Several stars; pale red.

To observe the intensity of light during the total eclipse.—Heavy, dull light; to the north, clouds, beautifully orange; to the eastward a grand sight, gold and rose color. (Here were inserted specimens of print, which were read at distances of six and ten inches.)

If the light increases towards the middle of the eclipse.—Too cloudy to observe.

Flight of the shadow eastward.—Too cloudy to observe.

Very respectfully,

H. B. NONES, JR.

*Observations of the seamen, as reported to Lieut. Comg. Murray, and by him presented to myself.**

REMARKS OF QUARTERMASTER.

First dark spot 9*h.* 5*m.* a. m.;† bore S. by W.; barometer, 29.40.; thermometer, 58°, (aneroid barometer used;) wind, squally from NW. by W.; force, 7 knots.

9*h.* 35*m.*, a few drops of rain; low dark clouds to the NE.

9*h.* 45*m.* clouds thickening in the direction of the sun; wind steady, W.NW.; force, 1 knot; barometer, 29.37½; thermometer, 52°; moon bore SW. by S. ¾ S.; stars to the right of the sun and overhead.

10*h.* 35*m.*, wind, W.NW.; force, 6 knots; barometer, 29.37½; thermometer, 51°.

11*h.* 15*m.*, drops of rain.

11*h.* 23*m.*, last dark spot visible; sun bore SW. by S.; barometer, 29.40; thermometer, 56°; wind, W. by N. ¼ N.; force, 3½ knots.

REMARKS MADE DURING THE ECLIPSE OF THE SUN, AS SEEN FROM THE STEAMER'S DECK.

1. *The fading of the light, the color of the clouds, landscape, &c.*—At 8*h.* 30*m.* a. m. the landscape began to wear a darkened appearance, and the water, in places, a greenish color. Sky covered with white fleecy clouds; thick, smoky mist overhanging the hills to the west. Wind strong and squally from NW. by W.

At 9*h.* 5*m.* a. m. eclipse began to come on upon the upper right hand limb of the sun; light fading gradually; clouds wearing a dark grayish color; landscape growing dark and gloomy. Sun bore S.SW.; wind, squally at intervals. Barometer, 29.40; thermometer, 58°.

At 9*h.* 45*m.*, sun passing through thick dark clouds.

At 10*h.* the sun emerged into a clear sky; landscape nearest the sun wore a dark, gloomy aspect, on the opposite side a grayish color; wind decreasing, and blowing from the direction in which the sun appeared to be moving.

At 10*h.* 13*m.*, as the sun becomes nearly obscured, the landscape presents a dark, gloomy, and dismal aspect; clouds of a dark leaden color.

2. *Whether we can see a star a little below and to the right of the sun before the eclipse is total, and for a little while after the sun begins to appear again.*—We observed no star before the eclipse became total, when we saw *four* stars, the bearings of which we noted. The fourth star was a little lower than the sun, and to the right of it; apparent distance, a quarter of a mile.

After the eclipse is total:

3. *Color of the sky, clouds, and landscape.*—At 10*h.* 15*m.*‡ sun totally eclipsed. All nature became enveloped in gloom and almost total darkness. You could just discern the black tops of the mountains that surrounded us. The clouds, too, were of a dark leaden color. Just as the sun emerges from the clouds, and as the eclipse begins to go off, then appears, right above the left side of the upper limb, patches of bright yellow and purple clouds. The other clouds were of a dark heavy color, but soon brightened up.

4. *How many stars they can see, and their colors; if any are red when seen by us.*—Soon after the sun became totally darkened, moon bearing SW. by S. ¾ S. We observed stars. The first seen bore SW. by W.; *second*, W.SW.; *third*, right overhead; *fourth*, nearly west, apparently one-quarter of a mile distant from the moon, and of a yellowish color.

5. *The appearance of the shadow as shown by the darkness of the sky and landscape towards the west.*—From the clouds which were constantly obscuring the sun we were unable to observe the approach of the shadow until it actually touched the upper limb of the sun.

6. *The degree of darkness to be noted by seeing how near, in inches, the eye must be brought to*

* Made on shipboard about ¾ of a mile SW. of the astronomical station.

† The watch or the clock employed seems, from the subsequent dates, to have been about 30*m.* *too fast.*

‡ This is a full hour in advance of the true date.

read a printed page; the number of inches to be marked in the book, so as to be recorded hereafter.—Everything became dark and gloomy. The degree of darkness was such that we could read an ordinary size print at 14 inches from the eye.

7. *Dark and light stripes flying over the ground just before the total eclipse; also, the quivering of the last beam of the sun just before it disappears.*—We observed a few shadows flying over the ground to the S.SE. The quivering of the last beams of the sun were very light, as seen by us.

8. *At the same time the like motion in the edges of the shadows; perhaps, too, the shadows may be colored.*—We observed a slight quivering in the shadows as they flitted over the landscape; likewise of different colors—red, green, and a yellowish white.

9. *Size of the bright ring around the moon; noticing whether the ring is a quarter as broad as the dark moon, or twice as broad, or how many times.*—The size of the ring appeared to be about one-third as broad as the dark moon, and of a bright radiant color, emitting quivering or sparkling beams of light, but uneven in its size and intensity all around.

10. *Whether the force of the wind is increased as the shadow approaches; and whether the wind then blows towards us from the shadow; and whether, as the shadow leaves it, blows back to us again from it; and whether there is a lull in the middle.*—The force of the wind was about seven knots until the dark shadows made their appearance on the landscape; then it became squally and fitful, but gradually decreasing in force as the darkness increased. I observed that whenever the sun emerged from the clouds those gusts of wind generally sprang up; wind blowing from the direction in which the sun appeared to move in, and gradually increasing in force until the sun became totally eclipsed, when it lulled down for a while; force then about one to two knots. Wind increased again as the eclipse was passing off; direction of the wind unchanged during the coming on and passing off of the eclipse.

JAMES COLLINS.*

NOTE BY LIEUT. COMG. MURRAY.—Six ducks put their heads under their wings, and apparently retired for the night.

Report of J. A. Osborne, surgeon's steward, on total eclipse of July 18, 1860.†

At 8*h.* 4*m.* a. m. a rainbow from the west, at foot of mountain, terminating in the midwater of the bay; sun, at time, luminous; western hemisphere, during the passage of the shadow, until the total eclipse, cloudy, gloomy, and dark, as if rain was threatening.

At 9*h.* 12*m.* darkness commenced; an appearance of gloomy night was fast approaching.

At 10*h.* 18½*m.*, mist of rain.

An appearance west, at 8*h.* 29*m.*, like unto rain clouds; back portion of sky (behind the clouds that floated in front of the shadow) very clear and blue in detached *parts.*

An appearance over the water of the bay, at 8*h.* 49*m.*, dark, and general surface of land very gloomy, as if obstructed by rain clouds; surface of ground darkened, as if before rain; wind, NW.

Upon the approach of the shadow:

Wind increased at	8*h.*	10*m.*
Wind mild at	8	27
Wind increased at	8	33
Wind increased at	8	36
Wind mild at	8	45
A lull	9	15

* Purser's steward.

† Observations made at meteorological observatory a short distance NW. of the station of the astronomical observers.

Upon the receding of the shadow:

Wind became mild at	9*h.* 35*m.*
Wind mild and sudden, in puffs, at	9 42
Wind increased at	9 56
Wind mild at	10 00

Direction of wind, NW.; from shadow, at 8*h.* 27*m.*, mild; back from shadow, at 10*h.*, (gloomy E. and W., bright N. and S.) Lull at middle, at 9*h.* 18*m.*

Force of wind:

At 8*h.* 5*m.*	7 knots.	At 9*h.* 18*m.*	1 knot.
At 8 15	4 "	At 10 00	2 knots.
At 8 36	6 "		

One star visible in the zenith of our position, as clear in appearance as usual with stars. No appearance of aurora. Comet not observable. No *red* stars seen.

At the time of total obscurity observed no halo or circle as it darkened, a cloud interfering at the time.

Respectfully, &c.,

J. A. OSBORNE.

Abstract of Mr. Goodfellow's report to the Superintendent.

SIDNEY, *Cape Breton, August* 3, 1860.

SIR: I have respectfully to submit the following report with regard to the determination of the magnetic elements near Cape Chudleigh, Labrador, in connection with the expedition to observe the total eclipse of the sun.

The station selected by the astronomers of the expedition was upon the northern end of Aulezavik island, in north latitude 59° 48′, longitude 4*h.* 17*m.* west of Greenwich.

The steamer came to anchor near this station on Saturday, July 14. As soon as a landing could be effected I went ashore with the *dip* circle, and made a preliminary series of observations at five different stations to ascertain the most suitable locality for magnetic observations. The position decided upon was as near the station of least dip as the nature of the ground would admit.

The next day, (Sunday,) the weather being fine and the necessity urgent, I had the tents and instruments sent ashore, and by night, with the assistance of Mr. Walker, had made partial adjustments of the declinometer and bifilar, in readiness for final adjustment the next day. These were not made without great difficulty, owing to the extraordinary changes of declination and horizontal force, due, to some extent, perhaps, to the presence of an aurora, which, on Monday evening, was observed by Prof. Venable shooting up in the northern sky nearly an hour before sunset.

The adjustment of the bifilar magnetometer was left entirely to Mr. Walker. By Monday night both instruments were in adjustment; two sets of vibrations had been observed with the declinometer, and one set of observations made for magnetic dip.

Early on Tuesday morning two more sets of observations were made; half-hourly readings of the bifilar were begun, and at 8 a. m. was commenced the series of half-hourly readings of the declinometer and bifilar for the twenty-four hours before and after the eclipse.

Very great changes of declination and horizontal force were observed throughout Tuesday; the vibration of the declinometer magnet, embracing an arc of five and a half degrees. There is no reason to suspect local attraction; no indications of the presence of magnetic oxide of iron were perceived.

The observations of both instruments, on the day of the eclipse, were made in accordance with your instructions, and the continuous series of half-hourly readings were kept up till Thursday at 2 p. m.

On Wednesday (18th July) and the day following, the changes of declination amounted to as much as two and a half and two and three-quarter degrees. On Wednesday the effect of the total darkness was apparently to diminish and, for a moment or two, almost to suspend the vibrations of the magnet, which seemed as if it were waiting the reappearance of the sun.

The remaining observations necessary to complete the series were obtained during Thursday and Friday, the greater part of Friday being occupied by Mr. Walker in observations of deflection and vibration, the latter being so arranged as to eliminate as much as possible the errors arising from the frequent and irregular changes of declination.

Observations were made upon the sun for azimuths.

On Friday evening the instruments were packed and sent aboard the steamer in anticipation of her departure the next day.

Duplicate records of the observations are now in preparation, and will be forwarded to you as soon as possible after the arrival of the vessel at New York.

Before the work can be computed, it may be desirable to determine the zero of the scale and moment of inertia of the declination magnet, unless recent determinations can be made available. The great changes of declination at the Labrador station made it impossible to get accurate results for these constants. The approximate declination may be stated as 51½ degrees west of north; the dip 82¼ degrees.

Mr. Samuel Walker took part in all the observations. To his skill and experience I am greatly indebted for whatever success has attended our joint labors.

Very respectfully, yours,

EDWARD GOODFELLOW.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

Recapitulation of observations for magnetic declination at Aulezavik, Labrador, 1860.

Date.	Latitude 59° 48′ N.					Telescope pointing W. of N.	Magnetic declination W. of N.	Longitude 4*h*. 17*m*. W. of Greenwich.			
	Number of observations.	Means.	Zero of scale.	Difference.	Difference in arc.			Maximum scale reading.		Minimum scale reading.	
								Time, p.m.	Scale.	Time, p.m.	Scale.
1860.					′ ″	° ′ ″	° ′ ″	*h. m.*		*h. m.*	
July 16	10	79.95	79.3	−0.45	−1 03.2	51 27 44.1	51 26 40.9	....	....	....	....
17	85	84.08	....	−4.78	−11 11.1	....	16 33	3 00	170	9 00	28.9
18	185	81.50	....	−2.20	−5 08.9	....	22 35.2	4 03	123.5	8 47	53.3
19	60	76.92	....	+2.38	+5 34.2	....	33 18.3	....	....	....	....
	340	81.29	....	−1.99	−4 40	....	51 23 04.1	....	....	....	....

Magnet b_{22}, one division scale = 2′.34.

	° ′
Mean magnetic declination, (340 observations)	51 23.1 W. of N.
Least magnetic declination, (3 p. m., 17th)	47 55.5 W. of N.
Greatest magnetic declination, (9 p. m., 17th)	53 25.7 W. of N.
Mean diurnal movement of needle	4 07.3
Least diurnal movement of needle	2 44.3
Greatest diurnal movement of needle	5 30.2

Abstract of observations for magnetic dip at Aulezavik, Labrador, 1860.

Date.	Needle.	Polarity.	Resulting dip.	Mean for N. and S. polarity.	Mean for both needles.	Time.
1860.			° ′	° ′	° ′	
July 16	1	S.	81 56.2			
	1	N.	82 12.3	82 04.3		
					82 09.1	5¼ p. m.
	2	S.	82 13.3			
	2	N.	82 14.4	82 13.8		
July 17	1	N.	82 22.4			
	1	S.	82 15.7	82 19.1		
					82 20.1	11 a. m.
	2	N.	82 17.2			
	2	S.	82 25.2	82 21.2		
July 18	1	S.	82 08.8			
	1	N.	82 06.0	82 07.4		
					82 09.6	3¾ p. m.
	2	S.	82 15.0			
	2	N.	82 08.4	82 11.7		
July 19	1	N.	82 22.6			
	1	S.	82 07.8	82 15.2		
					82 15.8	10¼ a. m.
	2	N.	82 16.8			
	2	S.	82 16.1	82 16.4		
July 20	1	S.	82 13.4			
	1	N.	82 18.9	82 16.1		
					82 17.7	11¾ a. m.
	2	S.	82 23.6			
	2	N.	82 15.1	82 19.3		
Mean					82 14.5	

Abstract of absolute determinations of horizontal force at Aulezavik, Labrador, 1860.

Declinometer D 22 —Magnets b_{2} and S_{2}.

Date of vibrations.	Beginning.	End.	Horizontal force.
	h. m.	h. m.	
July 17, 1860, a. m	5 24	6 10	1.666
July 19, 1860, a. m	10 49	11 25	1.712
July 19, 1860, p. m	1 03	1 39	1.727
July 19, 1860, p. m	10 35	10 55	1.731
July 19, 1860, a. m	0 50	1 10	1.703
July 20, 1860, a. m	8 36	8 58	1.687
July 20, 1860, a. m	10 31	10 51	1.692
July 20, 1860, p. m	0 15	0 35	1.709
July 20, 1860, p. m	1 18	1 36	1.718
July 20, 1860, p. m	2 40	3 01	1.699
July 20, 1860, p. m	3 31	3 55	1.690
Mean			1.703

Abstract of bifilar observations, corrected for temperature at Aulezavik, Labrador, 1860.

Date.	No. of observations.	Mean scale reading.	Bifilar reading for H. F. = 1.703.	Difference.		Resulting mean, horizontal force.	Minimum horizontal force.					Maximum horizontal force.				
				Scale.	Absolute horizontal force.		Time, a. m.	Bifilar reading.	Diff. from 102.1.	Diff. of absolute horizon'l force.	Horizon'l force.	Time, p. m.	Bifilar reading.	Diff. from 102.1.	Diff. of absolute horizon'l force.	Horizon'l force.
1860.							*h. m.*					*h. m.*				
July 16	3	79.6	102.1	—22.5	—0.020	1.683	......	....	....	....	....	......	....	....	....	....
17	81	93.4	....	— 8.7	—0.006	1.696	7 39	—28.5	—130.6	—0.115	1.588	5 15	174.1	+72	+0.063	1.766
18	197	89.1	....	—13	—0.011	1.692	6 03	+53.4	— 48 7	—0.043	1.660	4 07	146.6	+44.5	+0.039	1.742
19	49	66.3	....	—35.8	—0.032	1.671	6 35	—52.2	—154.3	—0.136	1.567	9 00	153.6	+51.5	+0.045	1.748
20	18	98.3	....	— 3.8	—0.003	1.700	7 45	+52.3	— 49.8	—0.044	1.659	0 35	121.3	+19.2	+0.017	1 720
	348	87.2	....	—14.9	—0.013	1.690	7 00	+ 6.2	....	....	1.619	4 44	148.9	....	....	1.744

Mean horizontal force, (348 observations)	1.690
Greatest horizontal force, (17th, 5¼ p. m.)	1.766
Least horizontal force, (19th, 6½ a. m.)	1.567
Mean daily change of horizontal force	0.0735
Greatest daily change of horizontal force, (19th)	0.1060
Least daily change of horizontal force, (20th)	0.0355
Mean horizontal force, 1,690, log	0.22789
Mean dip, 82° 14'.5, log	0.86968
Log. intensity	1.09757
Total intensity	12.519

Remarks by Assistant C. A. Schott on the magnetic constants found for Aulezavik, Labrador.

COAST SURVEY OFFICE, *Washington, D. C., October* 1, 1860.

DEAR SIR: The magnetic results of the Labrador expedition, made out by Assistant Edward Goodfellow, and sent to me in your letter of September 25, have been examined.

The declination, 51⅓° W., compares very well with Hansteen's value (47½° W.) for about the year 1820, (as lately published in his "Forandring, &c.") The value assigned by Evans' map for 1858, viz: 55° W., I think is too high, in consequence of too large a correction having been used for secular change. On Sabine's map for 1840 the declination given is 52° W. The diurnal variation is really very large at Kane's Winter Quarters, and with a dip of 84⅝° it was but little over 1°; hence with a dip of only 82¼° we might expect to find still less. The dip 82¼° compares well with Gauss' computed value, (83°,) and the intensity seems to agree with Sabine's deductions. At Cape Chudleigh the total intensity (12.52) is somewhat less than it is at Washington (13.5) or at New York, (13.3.)

Yours, very respectfully,

CHAS. A. SCHOTT,
Assistant Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

ADDENDUM.

Longitude by chronometers.

The results of the comparison of the other chronometers with that selected as the standard, show, in the case of most of them, quite small deviations on both sides from a uniform daily rate with reference to the standard.

This is most readily to be accounted for in so many instances by the hypothesis that *all* the instruments in question preserved *a nearly uniform sea-rate* during the outward and also during the return voyage. The error from Greenwich mean time, at the epoch of the eclipse, has accordingly been computed on this hypothesis for all the chronometers whose regularity (as thus manifested and otherwise exhibited) was such as seemed to render them available; the hypothesis, viz: of a uniform sea-rate from the day of sailing to the date of the *second* comparison of the instruments with the standard of the Messrs. Blunt, which comparison was, as near as might be, immediately on the steamer's return. For the single day which intervened between the *first* comparison with the Messrs. Blunt's standard and the time of our departure, the *shore-rate*, already ascertained, has been allowed in the instances of *Bond & Sons* 177, *Dent* 2602, *Fletcher* 1739, and *Dent* 2126, respectively.

In the instances of *Arnold & Dent* 802, and *Kessel* 1285, respectively, for which no comparisons in New York had been effected, the *errors* from *Greenwich mean time* for the first date of comparison of chronometers on shipboard, (*June* 29,) and also for the last date (August 7) have, respectively, been computed by first *deducing* the *error* for each of the two chronometers by a separate comparison with every one of *the other four*, (allowance being of course made for *their* errors and rates,) and then taking the mean of the results in the instance of each. The time is thus made to be dependent on the mean of the rates of the four other chronometers from June 27 to June 29 in the one determination, and from August 7 to August 10 in the other. As but one of the four rates in question exceeded 2*s*.5, and none of them had been much altered, and all were in the main well accordant, these deduced means of errors from Greenwich mean time, including accumulations through such short intervals, must be regarded as being in no small degree reliable.

Between the dates of June 29 and August 7 each of the two chronometers (*Arnold & Dent*, 802, and *Kessel's* 1285) has been presumed to have maintained (like the others also) its mean sea-rate, and the *error* from *Greenwich mean time*, at the *epoch of the eclipse*, been computed for each, independently of any other chronometer. Then the error from the *local mean time* was, in every case, obtained by comparison with the standard, (*Dent*, 2602,) and thus, with Bond & Sons 177, which was the chronometer made use of in our astronomical observations. The algebraical difference of the two errors of course gives the longitude.

The details of the computation are sufficiently exhibited in what follows; the sign + denoting *too fast*, as also a *gain* in rate, and the sign —, as the case may be, *too slow*, or *a losing rate.*

Chronometer—Bond & Sons, 177.

As determined by comparison with the standard of Messrs. E. & G. W. Blunt, of New York, we have, on June 27—

		h.	m.	s.
Error from Greenwich mean time	+		34	56.0
Daily rate	+			2.5
Error from Greenwich mean time, June 28	+		34	58.5
Error, determined as before, August 10	+		36	17.0
Gain in 43 days			1	19.5

giving a mean daily sea-rate of + 1*s*.85. Allowing this for $19\frac{7}{8}$ days, we have for—

		h.	*m.*	*s.*
Error from Greenwich, mean time, at the epoch of the eclipse	+	0	35	35.25
Error from local mean time	+	4	51	58.75
Resulting longitude		4	16	23.50

Dent, 2602.

Error, determined as before, on June 27	+	0	0	5.0
Daily rate	+			0.4
Error from Greenwich, mean time, June 28	+	0	0	5.4
Error from Greenwich, mean time, Aug. 10		0	1	9.0
Gain in 43 days	+		1	3.6

Which gives a mean daily sea-rate of 1*s*.48. Allowing this for $19\frac{7}{8}$ days, gives, for the error at epoch, + 34*s*.82.

Chronometer, by comparison with Bond & Sons, 177, on the 16th and on the 20th of July, found to be too slow	—	0	34	52.44
Bond & Sons, 177, too fast for local mean time		4	51	58.75
Error from local mean time	+	4	17	6.31
Error from Greenwich	+	0	0	34.82
Resulting longitude		4	16	31.59

Fletcher, 1739.

Error, June 27, from mean time, Greenwich	—		14	3.0
Daily rate	—			5.0
Error from mean time, Greenwich, June 28	—		14	8.0
Error from mean time, Greenwich, Aug. 10	—		17	22.0
Loss in 43 days	—		3	14.0

giving a mean daily rate of — 4*s*.51; from which we have, at epoch, error from mean time, Greenwich, — 0*h*. 15*m*. 37*s*.67.

Comparison with Bond & Sons, 177, on July 16 and 20, gives chronometer too slow	—	0	51	12.29
Error of Bond & Sons, 177, from local mean time	+	4	51	58.75
Chronometer too fast for local mean time	+	4	0	46.46
Error from mean time, Greenwich	—		15	37.67
Resulting longitude		4	16	24.13

Dent, 2126.

Error, June 27, from mean time, Greenwich	+	0	0	57.0
Daily rate	+			1.2
Error from mean time, Greenwich, June 28	+	0	0	58.2
Error from mean time, Greenwich, Aug. 10	+	0	0	37.0
Loss in 43 days	—			21.2

giving a mean daily rate of — 0*s*.493; from which we have, at epoch, error from mean time, Greenwich, + 0*h*. 0*m*. 48*s*.42.

		h.	*m*.	*s*.
Comparison with Bond & Sons, 177, on July 16 and 20, gives chronometer too slow	—	0	34	33.75
Error of Bond & Sons, 177, from local mean time		4	51	58.75
Chronometer too fast for local mean time	+	4	17	25.00
Error from mean time, Greenwich	+	0	0	48.42
Resulting longitude		4	16	36.58

Arnold & Dent, 802.

By comparison with Dent, 2602, on the 29th of June, and a deduction of error of the latter, allowing rates already exhibited, we have—

Chronometer too slow for mean time, Greenwich	—	3	57	52.32
Compared with Bond & Sons, 177		3	57	54.20
Fletcher, 1739		3	57	53.46
Dent, 2126		3	57	52.44
Mean error from mean time, Greenwich, on June 29	—	3	57	53.10
For August 7 we have, in the same order of comparison	—	3	53	31.29
Do		3	53	25.25
Do		3	53	26.98
Do		3	53	26.97
August 7, mean	—	3	53	27.62
June 29, mean	—	3	57	53.10
Loss in 39 days	—		4	26.42

When we have a mean daily rate of — 6*s*.832, and error from mean time, Greenwich, at epoch, — 3*h*. 55*m*. 44*s*.47.

By comparison on July 16 and 20, found to be to slow for Bond & Sons, 177	—	4	31	12.12
Error of Bond & Sons, 177, from local mean time	+	4	51	58.75
Chronometer too slow for local mean time	—	0	20	46.63
Too slow for Greenwich		3	55	44.47
Resulting longitude, W		4	16	30.60

Kessels, 1285.

Comparing as before, and in the same order, we have, on June 29, for error from mean time, Greenwich—

From Dent, 2602	—	5	8	22.72
Bond & Sons, 177		5	8	24.60
Fletcher, 1739		5	8	23.86
Dent, 2126		5	8	22.84
June 29, mean	—	5	8	23.50
Add for setting of chronometer	+		55	0.00
	—	4	13	23.50

		h.	m.	s.
On August 9, comparing, in the same order, we have	—	4	19	27.54
Do		4	19	21.50
Do		4	19	23.23
Do		4	19	25.18
August 7, mean	—	4	19	24.36
June 29, mean	—	4	13	23.50
Loss in 39 days	+		6	0.86

Giving a mean daily rate of — 9*s*.253, and error from mean time, Greenwich, at epoch, — 4*h*. 16*m*. 18*s*.76.

		h.	m.	s.
Comparison with Bond & Sons, 177, on July 16 and 20, gives chronometer too slow for Bond & Sons, 177, at epoch	—	4	51	48.21
Error of Bond & Sons, 177, from local mean time	+	4	51	58.75
Chronometer too fast for local mean time	+	0	0	10.54
Too slow for mean time, Greenwich	—	4	16	18.76
Resulting longitude		4	16	29.30

The several results for longitude are, respectively—

		h.	m.	s.
From Bond & Sons, 177	West of Greenwich	4	16	23.5
Dent, 2602	do	4	16	30.7
Fletcher, 1739	do	4	16	24.1
Dent, 2126	do	4	16	36.6
Arnold & Dent, 802	do	4	16	31.8
Kessels, 1285	do	4	16	29.3
Mean of the chronometers	do	4	16	29.33
The mean of the first four results is		4	16	28.72

The nearest whole second is, in both, 29*s*. We may, therefore, as at present advised, write the longitude of our eclipse station as being 4*h*. 16*m*. 29*s*. west of Greenwich.

If we adopt the equation of time given in the British Nautical Almanac, instead of that in the American, the longitude will be diminished 0*s*.36.

S. A.

College of New Jersey, *Princeton, November*, 1860.

APPENDIX No. 22.

An account of the total solar eclipse of July 18, 1860, *as observed for the United States Coast Survey near Steilacoom, Washington Territory, by Lieut. J. M. Gilliss, U. S. Navy.*

PRELIMINARY.

There seemed too little probability of favorable results from an expedition to observe the total eclipse from the west side of the American continent to justify the despatch either of many assistants or of an elaborate equipment of instruments. Experienced gentlemen, or those who were supposed to be so, and were consulted, pronounced that portion of Washington Territory which tho total shadow-path would traverse rugged, crossed by dangerous torrents,

caused by the snows melting at that season, and covered by dense forests, which would be likely to obstruct vision in almost every direction. They thought that a suitable site would be attainable only after cutting a path through immense forest trees to some mountain top of the Cascade range; and to accomplish this from Seattle, in the direction of the line of totality, involved a journey of five or six days on horses, and the fording of a stream (White river) which is perilous at all times, but is especially so at high water and with loaded animals.

Nor were their prognostications more flattering for the atmospheric condition on the morning of the eclipse. The hour of the day was against us, a law of meteorology to which that region forms no exception, and therefore they could offer few expectations of bright auroral skies to serve as encouragement during the certain, harassing forest struggle. They could safely promise a large proportion of clear afternoons in July, probably quite two-thirds of the whole number; but at the hour at which the eclipse would take place there, they thought we should be lucky if the mists and fog-banks from the Cascades and Puget sound permitted vision of the sun one morning of five.

Besides these natural hindrances, as the country is a newly settled one, great doubt was expressed whether proper transportation could be obtained from the proposed starting points for the land journey. Fortunately it was possible to provide against such contingency; for when the remaining portion of the programme was complete, General Jesup, U. S. A., very considerately instructed the quartermaster at Fort Vancouver, on Columbia river, to supply as many pack mules as might be required for the service, and thus allayed all anxiety on a very important question.

Having these several obstacles and risks clearly in view, two aids attached to the U. S. Coast Survey were designated to assist me in the observations, and, in the expectation that we should occupy an eminence of the Cascade mountains between lakes Kachess and Kitchelus, (lat. 47° 23′ N., long. 121° 28′ W.,) I regarded it indispensable to have as few instruments as would suffice for the work, and to have them distributed in light packages.

The assistants appointed were Messrs. A. T. Mosman and James Gilliss, both of whom were then on the West Coast of the United States. The former, who was supposed to be at Gray's harbor, was instructed to obtain, by personal examination and otherwise, all possible information of the country between the towns of Seattle and Steilacoom, Puget sound and White river, to ascertain whether men and animals could be had in that vicinity, and to report to me, on the arrival at Seattle of the steamer with the mail of May 21 from New York. Mr. Gilliss, then near San Francisco, was directed to meet me at that city, to have tents in readiness, and to make arrangements for a proper supply of provisions to last ten persons during sixteen days.

The instruments required for the party were:

1st. A telescope for my own use, to be mounted equatorially. Through the courtesy of Commander M. F. Maury, U. S. N., the comet-seeker belonging to the Washington Observatory was obtained. It is of the largest size, made at Munich by Merz & Mahler, viz: $3\frac{9}{10}$ inches clear aperture, and 34.6 inches focal length, with hour and declination circles of five inches diameter, and mounted on a heavy stand of brass, adjustable on foot-screws. As it was constructed for the Washington Observatory, whose latitude is (about) 39° N., and I contemplated occupying a station near the parallel of 47° N., a wedge-shaped plate of brass was fitted under its polar axis, in order to give the latter the requisite elevation. Its eye-piece also was specially prepared at the Coast Survey office. Improving upon the device adopted in Peru, in 1858, concentric circles, divided by diameters into octants, were engraved upon a plate of very thin glass, which was cemented at the focus of the lenses. The inner circle was (34′.9) intended to be (as it was pretty nearly) of the diameter of the moon as seen in the field on the morning of the eclipse; the next one of 5′, and the third of 8′ greater diameter, &c. The eye-piece magnified 32 times, and was furnished with a revolving disc, fitted with a series of differently tinted screen glasses.

2d. In accordance with a suggestion from Dr. B. A. Gould, a dark chamber, within which to observe the image of the sun when projected upon a screen of white paper, was fitted to Coast Survey reconnoitering telescope No. 10. The instrument is a 3-inch achromatic, of $46\frac{1}{2}$ inches focal length, mounted upon a common tripod of wood that permits vertical and horizontal motions, but which is without clamps or slow-motion screws. Its object glass appears to be an excellent one; the magnifying power of its eye-piece 50.

The dark chamber is a box of very thin pine boards, whose dimensions are $14 \times 10\frac{1}{2} \times 9\frac{3}{4}$ inches. Five sides of the interior are stained with lamp-black, the sixth covered with drawing paper. There is an aperture in the side facing the last, through which the eye end of the telescope passes tightly, and affords partial support to the box, the remaining weight being distributed between four brass rods, one end of each of which is soldered to a clamp fitted to the telescope tube, and the other ends penetrate corners of the box, where they are held by thumb-screws. One side of the box is hinged, to facilitate drawings. For observation of the magnified image upon the screen, there is an aperture sufficiently distant from the former to permit application of the eye without touching the telescope tube by the head. Thus the observer stands with his back to the object, and colored screen glasses are wholly dispensed with. The instrument would have afforded more interesting details but for its defective mounting, a result I am responsible for, because it was my duty, at least, to have seen the stand before unpacking it in Washington Territory.

3d. For the determination of the latitude of the station and its local time Coast Survey prismatic sextant No. 65, made by Pistor & Martins, and a mercurial artificial horizon were selected. The sextant is of ten inches radius, and reads by a vernier to 10″.

4th. Three chronometers. One of them was Coast Survey box sidereal chronometer No. 311, which was removed from its gimbals and packed in double and padded leather cases, fitted with straps for suspending it over the shoulders, and a belt to bind it to the waist. The others were mere mean time pocket chronometers, viz, No. 2113, with steel ands hand strongly-marked second's dial, and No. $\frac{2}{735}$. For the use of the latter instruments I am under obligation to Commander M. F. Maury, U. S. N. Neither of the three can be regarded a first-rate one.

5th. Meteorological instruments. Through the courtesy of Prof. Joseph Henry, these were obtained from the Smithsonian Institution. They consisted of a cistern barometer No. 1356, reading to *in.* .002, and a syphon barometer No. —, similarly divided; two air thermometers, Nos. A, 1637, and B, 1638, divided on ivory scales to 1°; two wet-bulb thermometers, with corresponding numbers, and lettered B, divided in the same manner on ivory, and two black-bulb radiating thermometers made in the same manner as the others. Each barometer was securely packed in an inner case of wood, and an outer one of leather fitted with transporting shoulder-straps. One thermometer of each kind was packed in a small box, and furnished with brass spring bracket and thumb-screws, by which to attach it to any convenient object. These instruments were made by Mr. James Green, of New York.

The remainder of the equipment comprised only a small lantern, a Nautical Almanac, and a table of logarithms. Except the chronometers and barometers, it was packed in three strongly-made boxes, provided with handles, to be used in case it became necessary to abandon their carriage on mules. When ready for transportation, they averaged rather less than one hundred pounds each.

Leaving New York per steamer of May 21, I crossed the isthmus of Panama on the evening of the 29th, and arrived at San Francisco on the afternoon of June 12. Mr. James Gilliss joined me at the latter city.

As the steamers from San Francisco to Puget's sound do not touch at Seattle, and Mr. Mosman had been directed to await me at the latter place, application was made to Messrs. Forbes & Babcock, the agents of the Pacific Mail Steamship Company, to permit a departure

from the regular itinerary of the voyage. And not only did these gentlemen promptly concede this important service, but they also instructed Captain Hudson, commanding the Panama, to facilitate my objects in every other manner in his power—an order which he most liberally and cordially interpreted, and executed on that as well as during the return voyage to San Francisco.

Two days later the instruments, tents, and provisions were shipped on board the Panama, by which steamer we left San Francisco at noon of 15th June, navigated the Columbia and Willamette rivers as far as Portland, in Oregon, and arrived off Seattle at 9 p. m., of the 22d. Mr. Mosman had not been there, and, as I afterwards learned, in consequence of there being no regular mail communication with Gray's harbor, his orders were not received until some days after my arrival in Washington Territory. On this account he was not able to join me until July 8.

Residents of Oregon and of Washington Territory, who had been fellow passengers with us from San Francisco, stated that there had been unusually heavy falls of rain (snow on the Cascade mountains) during the last winter and spring, and, in consequence of a continuance of the cold weather to a very late period, the annual freshets in the rivers had been very much delayed. We had seen the islands in the Columbia and Willamette rivers overflowed, and were told that those streams were, at least, ten feet higher than their usual level at that season of the year. It was reasonable to expect that the rivers of Washington Territory, which are further north, would be proportionally higher. Of the latter, and of the difficulties of crossing them with pack animals, reliable information was gained from an officer of the Hudson's Bay Company, who had made many journeys through the Yakima country between Vancouver, on the Columbia river, and Nisqually, on Puget's sound.

For want of the knowledge which had been expected through Mr. Mosman, as soon as it was satisfactorily ascertained that the number of animals required for transportation could not be obtained at Seattle, I deemed it proper to proceed to Fort Steilacoom, thirty-five miles further south, and consult with the United States officers there. Five hours later we landed at the village of the same name, which is located on the sound, a mile and a half to the west of the garrison.

While lying off Seattle a brilliant comet was seen in the northwest. At first I supposed it an auroral streamer, but its true character was instantly manifest when an ordinary ship spy-glass was turned upon it. This was the first clear evening experienced after passing Cape St. Lucas on the 8th June, and though there was still considerable twilight, and the moon was four days old, the comæ could be traced through more than 10° by the unassisted eye. The nucleus was quite distinct in the telescope. It was estimated to be about 1*m*. east, and 3° south of β Aurigæ. It was seen on the evenings of the 23d and 24th also. On the latter evening its tail was near 15° in length, and the nucleus had evidently moved to the south and east. When a telescope was unpacked, on the evening of the 26th, the portion of the heavens occupied by it was obscured by clouds, nor was it subsequently seen.

Brief conversation with the officers at Fort Steilacoom showed how little reliable was the topographical information previously obtained. They regarded the inference from the high water of the Columbia a just one as to the state of White river, but expressed every confidence that a journey to the summit of the Cascade mountains was totally uncalled for, if there was no other object in view than to obtain a horizon at sunrise, because they knew of many small open prairies west of the range which would permit vision of the sun almost, if not actually, upon the horizon. They were right. Two days afterwards an appropriate site for the observations was found about ten miles S.SE. from the garrison, and we encamped upon it on the morning of July 9 following, thus avoiding a hazardous, fatiguing, and costly journey to an inhospitable region, where a cloudy sky would most probably have attended us.

Topographical.—The spot selected for camp is a knoll of slight eminence on Muck prairie, west of the road, and one mile north of where a stream of the same name crosses it. The surface of the ground is rolling and the prairie about a mile wide between the nearest eastern and western belts of pine and hemlock trees. Two hundred yards north of the camp ground there is a clump of trees extending three-fourths of a mile from the road in a southeasterly direction, the eastern boundary of this clump being a nearly north and south line. Between the southeast corner of the clump and the eastern belt bounding Muck prairie there is an open space of half a mile which permits a view in the direction of sunrise, (at that time of the year.) Above the pine and fir-belt seen in this last direction, and some five miles distant, a very slight eminence of the Cascade mountains is visible, its elevation above the ground line being 32′ 20″. Assuming the (magnetic) variation to be 22° easterly, the bearing of the centre of the eminence is N. 64° E.; and that of Mt. Rainier, a lofty snow-clad summit of the same range, S. 33° E.

Between the forest bounding the southern line of the prairie and the Cascade mountains in that direction, the country is, apparently, much lower. A part of the mountain-ranges constituting the northern base of Mt. Rainier is visible over the eastern fir-belt and between the SE. by S., and south points of the compass, the entire chain is seen in broken ranges, the nearest of which is estimated to be 25 miles distant. The lowest depression in the range is the Cowlitz pass, which bears S.SE. Mt. Rainier appears as a triply pointed cone, covered with snow as far down as the forest permits vision—perhaps more than 10,000 feet! A most noble object it is to look upon.

After the tents had been pitched under the shadow of the trees, near the northwestern angle of the prairie, a computation of the sun's amplitude for the morning of the eclipse showed that the eastern extremity of the northern bounding pine-clump would obstruct the earliest rays. In consequence thereof, a site for the telescopes was selected S. 85° E., and 550 feet distant from the spot on which the observations for time and latitude were made. It is ten feet higher than the ground at the camp, and commands a better view to the northeast. From a mean of all the barometrical observations made at camp and reduced to 32° Fah., and upon the assumption that the barometer at the level of Puget sound reduced to the same temperature stands at 30 in., the elevation of the camp knoll is 350 feet; that of the telescope knoll 360 feet.

Adjustments and observations.—On the day after our arrival at camp the cistern barometer was suspended from a strong bracket nailed to the large oak tree which overshadowed the tent, and in such position that it was shielded from the sun in the morning by the tent; at noon by the trunk of the tree; and in the afternoon by a screen. Its cistern was two feet above the ground.

The air and wet bulb thermometers, Nos. 1637 A and B, were placed beside it, and the latter was moistened at least five minutes before reading it from a cup of water kept near.

The radiating thermometer was placed in front of the tent and its bulb just clear of the ground.

A wind-vane was made by tying a bit of tape to the highest twig of an oak bush from which all the branches had been cut, and staking the ground at the cardinal points. Our sheltered position rendered its indications doubtful at times, and, therefore, both the direction and the strength of the wind were quite as frequently estimated from the motions of the trees above and around us as from the vane.

These instruments were placed in charge of the assistants, and, except at 3 a. m., from which hour I excused them, observations were made tri-hourly until midnight of July 18. Those made at brief intervals, on the morning of the eclipse, by Mr. James Gilliss, are incorporated in the series.

At my request Dr. Joseph B. Brown, U. S. A., in charge of the hospital at Fort Steilacoom, very promptly and courteously promised a corresponding series for the morning of the eclipse,

and his observations are given elsewhere. If the temperature shown therein differs from that noted on Muck prairie more than the distance between the two places will satisfactorily explain, perhaps it may be accounted for by the fact that the thermometers at the latter were freely exposed in the open air, whilst those at the hospital are in a sheltered corner under a porch, on its south front.

Meteorological observations on Muck prairie.

Day and hour.	Barometer.	Thermometers. Attached.	Thermometers. Air.	Thermometers. Wet.	Thermometers. Radiating.	Wind. Direction.	Wind. Force.	Clouds.	Remarks.
1860.	*In.*	°	°	°	°				
July 10, noon.........	29.571	71.7	72.8	60.7	95.1	W.NW....	2	C. S. N. 10..........	Atmosphere hazy.
3 p. m..	557	77.7	76.6	65.7	92.0	E.NE......	2	C. K. 6..............	Very hazy.
6...	537	76.7	76.7	65.7	89.5	E.NE......	2	C. K. and K. S. 10....	Clouds very low; at least 10,000 feet; Mt. Rainier in sunlight.
9.............	521	66.5	68.6	60.6	....	Calm......	......	C. S. 10.............	Atmosphere hazy.
midnight......	536	62.2	62.6	57.5	....	Calm......	......	C. S. and K. S. 10....	Atmosphere hazy; heavy bank; cum. strat. to northwest.
July 11, 6 a. m.........	525	59.4	60.3	56.8	....	Calm......	......	K. S. 10.............	Atmosphere very hazy.
9 a. m.........	514	63.1	64.2	58.9	....	NW.......	2	N. 10......	Raining slightly.
noon..........	542	66.8	66.5	61.2	....	Calm......	......	C. K. and S. 10......	
3 p. m.........	555	67.8	67.7	60.3	....	NW. by W..	1	..... do	Do.
6.............	562	61.8	62.5	61.8	....	Calm......	......	Rain, 10............	Raining steadily.
9.............	602	58.9	59.0	57.9	....	Calm......	......	N. 10................	Do.
midnight	664	54.9	56.0	55.4	....	Calm......	......	Rain, 10............	Do.
July 12, 6 a. m.........	682	54.7	56.0	55.2	....	Calm......	......	N. 10................	Raining slightly.
9 a. m.........	668	59.8	60.1	57.9	....	SW.	2	K. and K. S. 10..	Sun through clouds.
noon..........	667	61.5	61.8	58.7	....	SW.	2	K. S. and N. 10..	Showers at intervals, light.
3 p. m.........	736	65.5	64.5	58.6	... .	SW.	2	K. and K. S. 10..	Raining one mile to southwest.
6 p. m.........	748	57.7	58.7	57.2	....	W.SW....	2	N. 10...............	Raining moderately.
9 p. m.........	766	57.0	58.1	56.3	....	W.SW....	1	N. 10................	Raining slightly.
midnight......	730	55.5	55.6	54.3	....	Calm......	......	K. S. 10.............	No rain; atmosphere clear.
July 13, 6 a. m.........	753	55.0	55.3	54.4	....	NW.	1	K. and K. S. 10.....	Clouds very low; atmosphere clear.
9 a. m.........	884	60.8	60.5	56.8	....	W.NW....	1	K. 7.................	Do. do.
noon..........	878	65.3	63.0	57.9	....	W.NW....	1	C. K. and K. 5.......	Do. do.
3 p. m.........	854	67.1	66.8	58.7	....	W.NW....	2	C. K. and K. 8.......	Do. do.
6 p. m.........	828	62.0	62.3	59.3	....	W.SW....	1	K. S. and N. 10......	Raining lightly.
9 p. m.........	821	59.7	59.8	55.7	....	W.NW....	1	K. S. 10.............	Moderately clear atmosphere.
midnight......	776	56.3	56.7	53 7	....	NW.......	1	K. 9.................	Black cloud to eastward; some stars.
July 14, 6 a. m.........	758	55.0	55.9	53.2	....	N.NW.....	1	N. 10................	
9 a. m.........	754	58.9	59.0	55.2	....	NW.......	1	C. and C. K. 6.......	Sun through clouds occasionally.
noon..........	766	67.8	68.0	59.2	94.0	NW.......	1	C. and C. K. 4.......	Atmosphere moderately clear.
3 p. m.........	724	70.3	70.0	59.4	80.0	West......	2	K. 7.................	Sun occasionally obscured.
6 p. m.........	708	70.7	70.8	58.2	85.6	NW.......	½	K. S. and S..........	Centre of Rainier seen through clouds.
9 p. m.........	676	59.4	59.2	55.0	....	NW.......	½	O.	Atmosphere clear.
midnight......	694	53.2	53.1	51.4	....	Calm......	......	K. S. 1..............	Some clouds to south.
July 15, 6 a. m.........	664	53.0	53.6	52.0	64.0	W.SW ...	1	K. and K. S. 1.......	Top of Rainier in clouds.
9 a. m.........	656	65.5	66.7	60.0	87.5	E.NE......	1	K. and K. S. 4.......	Haze over Rainier.
noon.........	638	72.3	72.8	61.9	93 2	N.NE.	2	K. 1.................	Clouds about eastern horizon.
3 p. m.........	610	77.5	77.2	62.3	88.0	N.NE.	2	K. 1.................	Do. do.
6 p. m.........	613	71.7	72.0	60.3	....	NW.......	3	K. and K. S. 8.......	Sudden squall from northwest.
9 p. m.........	710	59.6	59 7	55.4	....	NW.......	2	K. S. 10.............	Distant thunder between 9 and 10 p. m.
midnight......	700	57.8	58.1	53.8	....	Calm......	......	N. 10................	
July 16, 6 a. m.........	772	55 8	56.1	52 0	....	W.SW....	2	N. 10................	Cascade range invisible.
9 a. m..	816	61.0	61.0	54.2	....	NW.......	1	K. and K. S. 10.....	
noon..........	851	64.4	64.4	56.5	....	W.SW....	1	K. and K. S. 10......	Atmosphere very clear.
3 p. m.........	836	67.9	67.0	57.4	91.0	W.SW....	2	K. S. 8..............	
6 p. m.........	818	66.6	65.8	55.7	82.0	W NW....	1	K. and K. S. 2.	Top of Rainier visible over clouds.
9 p. m.........	802	55.2	56.5	54.2	....	Calm......	......	K. and K. S. 1.......	
midnight......	800	49.5	49.6	48.3	....	Calm......	......	O.	
July 17, 6 a. m.........	796	50.2	50.8	49.6	55 0	S.SW.	1	K. S. 1..............	
9 a. m.........	799	64.8	64.3	55.8	90.4	NE........	2	K. and K S. 2.	
noon..........	29.752	68.0	67.9	57.4	95.0	West......	2	K. 2.................	Top of Rainier distinct; wind in squalls.

Meteorological observations at Muck prairie—Continued.

Day and hour.	Barometer.	Thermometers. Attached.	Air.	Wet.	Radiating.	Wind. Direction.	Force.	Clouds.	Remarks.
1860.	*In.*	°	°	°	°				
July 17, 3 p. m........	29.758	72.7	72.4	58.5	100.5	NW.......	1	K. ½..................	Top of Rainier distinct; wind in squalls.
6 p. m........	732	70.7	70.3	58.8	77.0	North......	2	K. S. ¼.............	Do. do.
9 p. m........	700	54.3	54.9	51.0	....	North......	1	O.	
midnight......	684	50.6	51.5	49.0	....	SW.......	1	O.	
July 18, 4*h*. 0*m*. a. m..	686	44.3	45.7	44.5	....	Calm......	......	O.	Light haze to eastward.
10.........	686	44.5	45.3	44.6	....	Calm......	......	O.	Do.
20.........	678	44.0	45.1	44.3	....	Calm......	......	Stratus 1	Rainier very distinct.
30.........	690	43.9	45.0	43.9	....	Calm......	......	... do	Clouds only to southeast.
40.........	690	44.0	44.9	44.0	44.0	Calm......	......	K. S. 1...............	Only cloud is on Rainier.
50.........	698	43.5	44.0	43.2	42.7	South	1	....do	
5 0.........	692	43.0	44.0	43.2	43.1	South	1	....do	
10.........	676	43.9	44.0	43.8	45.0	South	1	K. and K. S. 2.	Rainier only partly visible.
20.........	680	45.8	44.9	44.0	50.0	SW........	1	K. 3..................	Rainier entirely hid.
30.........	688	47.3	45.9	45.1	51.0	S. SW.....	1	K. 3..................	Large cloud to southwest.
40.........	698	50.6	47.0	46.2	55.0	SW........	1	C. S. 3......	
50.........	720	51.5	49.0	48.7	55.0	South	1	C. S. 5...............	Sun obscured by clouds.
6 0.........	730	51.4	51.2	49.9	....	South	1	C. S. 9......	
9 0.........	740	60.1	60.5	55.7	92.0	SW........	1	K. 3..................	Atmosphere moderately clear.
noon..........	708	59.3	68.7	58.8	95.0	NE.........	1	O.	Atmosphere clear.
3 p. m........	666	74.7	74.8	59.0	96.5	North	2	K. 1..................	
6 p. m........	632	72.2	72.1	58.2	83.0	North	2	O.	Slight K to northeast and south southeast.
9 p. m........	618	58.7	58.6	53.9	....	North	1	O.	Rainier very indistinct.
midnight......	29.618	52.5	53.1	51.5	....	North	1	O.	

NOTE.—In the column clouds, C signifies cirrus; K, cumulus; S, stratus; N, nimbus; O, clear sky; 10, entirely cloudy. In the column wind, 1 signifies light breeze; 10 gale.

Observations for time and latitude were made with the sextant and artificial horizon morning, afternoon, and night of every available day whilst we were in camp. The inverting telescope and highest magnifying power were used throughout. The index error was ascertained both morning and afternoon by at least three measurements of the sun's diameter, on and off the arc. Whether its steady increase during the earlier days of observation was an actual progressive change, or only an apparent one, arising from want of experience with that particular construction of instrument, I cannot say.

The computations have been made by Mr. John Wiessner, U. S. Coast Survey, and the data and results for latitude are given in the following table:

Observations for latitude.

July 13, 1860. Sun's lower limb. Index error sextant — 41″.6. Barometer, 29.878 in. Attached thermometer, 65°.3. Air, 63°.0. Apparent noon, 8*h*. 15*m*. 29*s*. per No. 2113.

Time per 2113.	Double altitude.	Hour angle.	Reduct. to meridian.	Meridian altitude.	Mean.
h. m. s.	° ′ ″	*m. s.*	′ ″	° ′ ″	
8 5 32.4	128 42 40	— 9 57	+ 4 44	64 26 4	
7 47.1	46 0	7 42	2 51	25 51	° ′ ″
8 40.2	49 10	— 6 49	2 13	26 48	64 26 22
17 34.9	53 10	+ 2 6	13	26 48	
25 29.1	43 50	10 0	4 46	26 36	
31 50.6	26 40	+16 21	12 46	64 26 06	

Semid. + 15′ 46″.2. Refrac. — 27″.2. Paral. + 3″.8. Dec. + 21° 43′ 50″.2. Lat. + 47° 2′ 26″.2.

Observations for latitude—Continued.

July 16, 1860. Polaris east of meridian. Index error sextant — 64″.1. Barometer, 29.800 *in*. Attached thermometer, 51°.8. Air, 52°.7.

Time per 2113.	Double altitudes.	
h. m. s.	° ′ ″	
18 11 33.8	93 4 40	No. 2110 fast mean time, 8*h*. 9*m*. 50*s*.
13 6.9	5 30	Sid. time observation, 17*h*. 45*m*. 54*s*.6.
14 39.8	6 40	α = 1*h*. 8*m*. 12*s*. Δ = 1° 26′ 15″ = 5175″.
15 58.8	7 40	Refrac. 54″.6. h = 4*h*. 37*m*. 42*s*.6. = 69° 25′ 39″.
17 32.1	93 8 40	Δ cos. h = + 1818″.5.
		½ sin. 1″ (Δ sin. h)². tang. A = + 60″.0.
18 14 34.3	93 6 38	⅙ sin. ²1″ (Δ cos. h) (Δ sin. h)² = + 0″.3.

Lat. + 47° 3′ 11″.2.

July 18, 1860. Altair west of meridian. Index error sextant — 60″.0. Barometer, 29.618 *in*. Attached 52°.5. Air 51°.5.
Altair's α = 19*h*. 44*m*. 1*s*. δ + 8° 30′ 12″.2. No. 2113, fast sid. at transit, 20*m*. 26*s*.; losing 3*s*. daily.

Time per No. 2113.	Observed double altitudes.	Sid. int. from meridian.	Reduct. to meridian.	Meridian altitude.	Mean.
h. m. s.	° ′ ″	*m. s.*	′ ″	° ′ ″	
20 8 12 9	102 55 10	+ 3 47	+ 0 30	51 28 5	
13 19.2	52 0	8 53	2 46	46	
13 51.2	50 50	9 25	3 6	31	51° 28′ 23″.4
14 31.6	49 20	10 7	3 36	16	
15 11.1	48 10	10 46	4 4	9	Refrac. — 45″.6
16 23.0	47 0	11 58	5 1	31	
17 14.2	45 20	12 49	5 45	25	
20 18 17.6	102 43 20	+ 13 53	+ 6 44	51 28 24	

Latitude + 47° 3′ 4″.4.

Combining the three sets, with weights proportional to the number of observations in each, we have for the camp knoll latitude + 47° 2′ 54″.1, and for the site on which the eclipse was observed—

Latitude + 47° 2′ 54″.

The observations and data necessary for the determination of the local time and errors of the chronometers are shown in the following tables:

Comparisons of chronometers.

Date.	No. 2113.	No. $\frac{2}{739}$	No. 311.
1860.	*h. m. s.*	*h. m. s.*	*h. m. s.*
July 13............	4 59 0.0	4 58 38.9	5 3 33.3
15............	4 43 0.0	4 42 37.8	4 55 42.7
16............	11 41 0.0	11 40 47.2	12 59 12.3
17............	4 44 0.0	4 43 49.5	5 5 8.3
18............	4 38 0.0	4 37 51.2	5 3 14.3
19............	4 10 0.0	4 9 51.1	4 39 17.8

Observations for time.

Date.	Object.	Mean of times per No. 2113.	No. of observations.	Mean of observed double altitudes.	Index error.	Barometer.	Thermometer.		No. 2113, fast of M. T.
							Altitude.	Air.	
1860.		*h. m. s.*		° ′ ″	″	*Inches.*	°	°	*h. m. s.*
July 13	$(\underline{\odot})$	4 34 26.9	5	77 54.16	−41.6	29.884	60.8	60.5	8 10 2.7
14	Arcturus	17 38 49.2	5	91 34.22	41.6	.705	59.3	59.5	0.4
15	$(\underline{\odot})$	4 33 44.8	5	77 10.12	50.0	.660	64.0	65.0	0.8
15	$(\overline{\odot})$	11 15 11.2	5	92 7.40	57.5	.610	77.5	77.0	3.4
16	$(\overline{\odot})$	11 13 44.0	5	92 20.4	64.1	.836	67.9	67.0	9 51.6
16	$(\underline{\odot})$	11 18 14.2	5	89 50.2	64.1	.836	67.7	67.0	51.0
16	Arcturus	17 7 25.1	5	98 45.32	64.1	.802	55.2	56.5	49.8
17	$(\underline{\odot})$	4 15 38.4	5	70 37.26	57.5	.816	60.8	60.3	49.5
17	$(\overline{\odot})$	11 45 23.0	5	81 45.10	62.5	.755	72.1	71.4	45.6
17	Arcturus	17 28 2.6	5	91 11.4	62.5	.700	55.5	55.3	46.7
18	$(\overline{\odot})$	4 32 20.2	5	77 2.10	62.5	.732	58.9	59.0	47.3
18	$(\overline{\odot})$	12 21 45.5	5	69 18.42	−60.0	29.658	73.5	73.6	8 9 45.1

It was known at departure from New York that chronometer No. 311 was altogether too irregular in its going to justify confidence in a longitude derived from it. The errors on mean Greenwich time and rates of the others, given by Messrs. Eggert & Son, and derived from the preceding table, were:

Chronometer errors and rates.

Chronometer.	Error, May 21.	Error, Aug. 24.	Daily rate, May 21.	Daily rate from July 13 to 18.	Daily rate from May 21 to Aug. 24.
	m. s.	*m. s.*	*s.*	*s.*	*s.*
No. 2113	+0 6.5	−1 23.5	+0.2	−3.31	−0.95
No. $\frac{2}{739}$	+1 11.5	−2 7.0	+0.5	−0.62	−2.09

From the errors on local time, derived from the morning and afternoon observations of July 18, and those on mean Greenwich time, shown on returning to New York, August 24, the several rates applied to the latter date give the following longitude for the camp knoll:

Longitudes, camp on Muck prairie.

Chronometer.	From rate of May 21	From rate of 13th to 18th July.	From rate of 21st May to 24th August.
	h. m s.	*h. m. s.*	*h. m s.*
Number 2113	8 11 16.44	8 9 8.33	8 10 33.89
Number $\frac{2}{739}$	8 12 2.24	8 11 22.56	8 10 26.41
Means	8 11 39.34	8 10 15.44	8 10 30.15

The correction applicable to observations at camp to reduce them to the telescope knoll being — 0*s*. 56; if we adopt the determination from the rates between 21st of May and 24th of August as the most reliable we shall have for the spot on which the eclipse was observed

Longitude 8*h*. 10*m*. 29*s*.6.

The telescopes were removed to the knoll east of the camp during the morning of the 17th,

and after the stand of the comet-seeker had been adjusted for verticality by the level attached thereto, its polar axis was (first) brought approximately in the meridian by means of a pocket compass divided to 1°. Its eye end was next turned until the motion of the sun was parallel to one of the lines engraved on the glass lamina, and then the focus was adjusted upon the sun's limb and spots. At later hours the diameters of the inner engraved circles were measured by transits of the sun's limbs over them, and the azimuth of the polar axis examined at the eastern elongation of Polaris. No attempt was made to correct for any error that might have existed in the elevation (47°) of the polar axis.

The other telescope was placed a few feet to the south of the comet-seeker, the top of its stand made horizontal, and the tripod legs pressed firmly into the ground whilst so adjusting it. Its eye-piece was then moved until the sun's image cast upon the screen was the sharpest, and at the same time two of the shadows of the engraved lines on the diaphragm were respectively parallel with and perpendicular to the top and side of the box.

Each of the assistants had carefully studied the suggestions prepared for the Coast Survey observers by Dr. B. A. Gould and Prof. Jos. Henry, and the duties assigned to them were briefly as follows:

Mr. Mosman had had some experience in astronomical observations. The telescope with dark chamber, the sidereal chronometer, and sheets of paper with circles drawn upon them to correspond with the images of those in the diaphragm were therefore given to him. A differently mounted instrument would have afforded him ample materials for notes and drawings of the phenomena.

The meteorological instruments were suspended from a temporary tripod erected just west of the telescopes, and were placed in charge of Mr. James Gilliss, who was also to record changes in colors, the amount of light, and all other information not requiring the use of a telescope. For the purpose of aiding him in recognizing and distinguishing them a diagram had been prepared to show the places of the planets and brighter stars then in the vicinity of the sun. These duties were deemed quite sufficient to occupy him without the additional task of calling aloud the seconds of a chronometer, as proposed by Dr. Gould, for one assistant, (of three,) and therefore Mr. Mosman and myself were each to note time for himself, to which end I had chosen the chronometer with steel hands.

THE ECLIPSE.

For the first time after our arrival at the station selected the sun rose clear on the morning of July 17th, nor was there more than two-tenths of the sky obscured by clouds at any time during that day. But I had no confidence in the state of the weather. The experience of three weeks in Washington Territory had been of rapid change from fair to mist, or fog, or cloud, sometimes over one, sometimes over another part of the heavens, and the prognostics one has a right to make from ordinary meteorological intelligence were constantly at fault. Therefore, although the evening of the 17th was absolutely cloudless, and the stars were shining with remarkable lustre after midnight, yet when we closed the tent, three hours before the eclipse began, neither of us could venture to predict a favorable morning for the observations.

By half past three a. m. we were up and had removed the meteorological instruments to the telescope knoll. Even at that time it was sufficiently light to write without artificial aid. Mount Rainier was distinctly visible and sharply cut against the southeastern sky, its towering cone of snow mellowed to a bluish glacier tint. Beyond it, and thence northward in the direction of sunrise, there was a stratum of vapor whose upper line was slightly inclined from mid-height of the mountains to the horizon. The barometer stood at 29.698 *in.*; attached thermometer 44°.5; temperature of the air 45°.2; and there was only a very light air from the southward.

At *4h. 6m.* the mist striæ became denser to the northward and eastward. They were more evidently in rays diverging from the point occupied by the sun, and were traceable to an elevation of 25° at the extreme limit southward. Then the air was so loaded with moisture that the cold was exceedingly penetrating, and although the telescope had been completely exposed all night the object glasses were densely covered with drops very soon after the caps were removed.

By *4h. 19m.* a part of the vapor to the northeast had condensed beyond the Cascade mountains into little cumuli, each one more light and feathery with its distance from the diverging point, though none of them extended so far as Mount Rainier, and it was only to the southward of the peak that a broad volume of vapor was seen pouring through the Cowlitz pass towards the low lands bordering on Puget sound. Two minutes later and the edges of the little floculi were bordered with hues of pink and gold, which increased in depth and brilliancy of color as the sun approached the horizon.

The moon had advanced far upon the sun's disc when the first cusp appeared on the horizon at *4h. 29m. 52s.* It was seen through a red screen glass, and the image was sharp and without tremor. Indeed, the atmosphere was so still that the rise of the second cusp over the distant ground line at *4h. 31m. 10s.* was observed with almost as much precision as its transit could have been over the wire of a meridian telescope. But it was at once perceived that there was great distortion of the lune, unequal refraction apparently flattening its lower half.

Immediately thereafter it was again necessary to wipe the heavy dew drops from the object glass of the telescope, and whilst so doing my attention was directed to the surface vapor which had formed near us. Apparently the whole of the northeastern and lower portion of the prairie was a placid lake embowered among towering pines and hemlocks, and dotted with miniature isles, an illusion which was enhanced by rapidly diminishing intensity of the sunlight. It was so still and so smooth that I almost expected to see reflections of the trees and shadows of the knolls which formed its islets.

At *4h. 43m.* distant objects could not be recognized more distinctly than during midsummer twilight in latitude 45° at 8½ p. m.; and though Mt. Rainier still reflected rays from the sun, the sky beyond it and in every direction from us was of a leaden hue and without transparency. The countenances of the assistants had become of a greenish-yellow color, and the ever dark-green forests were really black.

At *4h. 44m.* the southern cusp had become rounded off and jagged, as though the moon's edge was serrated. But had such been the case this portion of the lune would have been broken into beads of light before the total obscuration took place, a phenomenon which did not occur, the moon's disc equally and uniformly interposing between us and the sun until the last particle of light vanished at *4h. 47m. 29s.9.* I must not be understood as meaning to convey the idea that the attenuated diminishing crescent was a constantly continuous band of light, uniformly disappearing from the two extremities, for such was not the case. Though never of that silvery color, both horns resembled the surface of the moon just coming into sunlight when many portions are brighter than others, and sometimes from one and sometimes from the other considerable portions dropped off like filaments of melting metal.

I had turned off the red screen half a minute before, and was quite surprised that the following segment of the lunar sphere was distinctly visible through more than 100°. Its color was uniformly shaded from an intense black at the centre to a dark grayish purple on the western border, and for the first time in my life the moon was visible in its true form—a sphere and not a disc. There was as great a difference between its appearance then and that to which I had been accustomed, as there is between a single photograph and a stereoscopic picture. This spherical figure was traceable during *20s.* after the last glimmer of sunlight.

At the moment of totality beads of golden and ruby-colored light flashed almost entirely around the moon. They were not constant in dimensions or color at one point, even for a

second, but fitfully flickering, as reflections from rippled water, and as mutable in the respective places of color. I do not think this band could have been more than 10″ or 12″ broad. It was generally separated from the sharp lunar disc by a delicate line of white light, which disappeared as the changes of form or color took place. It broke up suddenly at *4h. 47m. 56s.5*, and then for the first time protuberances were noted beyond the following limb of the moon. The position of the largest one was S. 75° or 78° W., and its general form that of a flattened cone or pyramid of cumulus cloud, which, when first observed, was perhaps 2′ broad at the base, and 1′ high. It was not regular in outline or uniform in color, but apparently an aggregation of smaller clouds, tinted a rosy pink at the denser portions, but with edges and occasional spots of yellowish-white, as though sunlight shone obliquely through them. Except in the pink color, it greatly resembled the protuberances noted during the total eclipse of the sun observed at Olmos, September 7, 1858. As the moon moved onward it was certainly broader at the base and brighter at the summit than when first recognized, though I cannot say that its apparent altitude was increased thereby. Nevertheless I am positive that it was uncovered by and did not follow the moon. Synchronous with this, a smaller mass of a more flattened appearance, but having the same colors, was visible 10° or 15° towards the west, and many other lesser ones at different points of the disc. Only the places of these two were recorded at the time. At a later period a continuous chain, more than 30° long and above 30″ high, was seen on the S. E. border. This also was sketched. Its edge was exceedingly ragged, and the rapid view given to it impressed me that its color was dark—quite as obscure as that of lead, which is presumptive evidence of the presence of the corona light, though the latter had not then arrested attention. In fact, believing that more valuable information would be gained by closely observing one of the prominences than from an effort merely to locate many or the coronal phenomena, I had given nearly my whole time to the extremely brilliant and beautiful object whose description has been attempted. This examination confirms an opinion formed in 1858, and I am most thoroughly convinced that the masses which became visible apparently around the lunar disc were really clouds belonging to the solar atmosphere.

Two illustrations for different periods of the eclipse have been prepared by Mr. McMurtrie, U. S. Coast Survey, from my rough sketches and verbal account. They embrace all the phenomena witnessed at any time during the totality, of which a record was made at the time. Figure I (Sketch No. 39) is not strictly in accordance with fact, because the moon has been intentionally represented under its most spherical aspect, which was actually before the final occultation. Moreover, the dimensions and places of the filaments composing the colored circles are intended as illustrative of the general appearance, and not as a photograph of the actual picture.

Interest in the principal solar cloud not only caused temporary forgetfulness of the corona, as has been acknowledged, but also the beat of the chronometer had been lost, and as the total phase was passing rapidly it became necessary to look at the dial of the instrument again. This afforded an opportunity to glance at objects between the northeast and south-southeast points of the landscape without rising from my chair. But it was dark as night, and only a shadowy outline of the near forest could be seen; all beyond it, even the snow mantle of Mount Rainier was lost in the deep gloom. I was seated entirely free from bodily constraint, with the chronometer on the telescope-stand and within two feet of the eye; but as it was too obscure for me to distinguish the marks of the second's dial, even when stooping to within a few inches of them, Mr. James Gilliss was warned to bring his lantern and record the time at which I should indicate the second internal contact of the two limbs.

I could not have been bent over the chronometer more than *8s.* or *10s.* before my face was again lifted towards the telescope, and in so doing a most extraordinary scene was apparent. A totally different picture had been substituted for the black disc which only a brief instant before was seen circled by a tremulous band of vermilion or red, and yellow lights, overlapped

by the solar clouds. True, the disc was there, but it was thrown in bold relief upon a ground of virgin white, traceable in every direction for the distance of quite a semidiameter. The solar clouds were there also, but the gorgeous circlet was gone, and over the jetty surface, colors of the spectrum apparently flashed in circular bands of equal diameter with the moon. A spectacle so remarkable thoroughly startled me from the equanimity with which the preceding phenomena had been observed, and I was irresistibly drawn to its contemplation, to the neglect of changes that might have been taking place in the borders of the solar clouds and corona.

As near as it was possible to estimate them, each band or circular segment was about 2′ broad. Its colors were crimson or red, violet, yellow, and green, the last one being on the edge over the lunar centre, and of a tint not darker than that known as pea-green. The bands of red and green were wider than those of violet and yellow. They were not visible beyond the borders of the moon, and as each seemed to be in rapid revolution downward towards the lunar centre, their relative places appeared to be incessantly changed, like those of a kaleidoscope, more closely than anything else with which I can compare them. They continued visible with the telescope at least 10*s.* longer, and vanished at 4*h.* 49*m.* 25*s.*3 with the first appearance of the sunlight beyond the western limb of the moon, their sudden obliteration causing me to utter an exclamation which was regarded as the signal for noting the time, a datum whose importance had been forgotten in the fascination thus caused.

Figure II (Sketch No. 39) is intended to represent the phase of the eclipse just described. The proportions and angles of position are correct. Apparently the colors are a little too deep, but this would disappear was it possible to imitate the exquisite shading of the natural spectrum, a difficulty which augments rapidly as the scale of the picture diminishes. In the present case the imperceptible passing from one color was simply impossible. Both representations are as seen in an inverting telescope, the upper points of the discs being south.

Was the phenomenon wholly physiological? The dimensions and relative places of the prismatic segments are in accordance with the law of accidental or subjective colors, and seem to indicate it. But if so, the spectrum bands should have been seen immediately after taking the eye from the telescope, whilst I was bending over the chronometer in efforts to recognize the divisions of the seconds dial, and when, if ever, the images of the brilliant colors around the lunar border should have been vivid. This was not the case, nor were they perceived until at the instant of looking upward from a small object on which (the chronometer being in a mahogany box) the only colors were porcelain white and Japan black. This fact, its subsequent visibility in the telescope, and the analogous, if not precisely similar spectacle, seen by Mr. Goldsborough from Fort Steilacoom, seem to justify a doubt whether it can be attributed to an abnormal condition of the retina.

The contemporaneous presence of a corona light with the prismatic segments has been adverted to, as well as the fact that the latter had monopolized my attention. In consequence of the monopoly, I can only add to what has been mentioned of the former; that it was composed of radial beams or streamers with slightly darker or fainter interstices, rather than of a disc of regularly diminishing or suffusing light, and that it was apparently concentric with the moon, from whose border outwards the light grew less and less until totally lost at the distance of 15′ to 18′.

Within five seconds after the sun emerged, I looked carefully for the corona and greater solar cloud, and then for the eastern limb of the moon, but not the slightest trace could be seen of either of the former. There was a faint edging of ruddy light near that border of the moon, and close examination enabled me to detect a dark purplish shading from thence towards its centre; but it continued only a very brief period, and even when the shading was most distinct the globular figure was not a characteristic as before the totality.

The termination of the total phase permitted me to look at surrounding objects. Again the object-glass of the telescope was found to be excessively wet, and the tube and stand, neither

of which had been wiped on the previous occasions, were literally dripping with moisture. At 4*h*. 50*m*. the countenances of the assistants were more pallid and corpse-like than at 4*h*. 43*m*., and light seen against the forest belts was of a sickly yellow hue. Interposing my hand so as to cut off direct rays from the sun, the northeastern sky was of a dark purple; Mount Rainer, to the southeast, of a soft, milky hue. From thence to the southwest the color changed by imperceptible degrees to a greenish blue, or perhaps more nearly a bronzed blue; and finally, in the same circuit to the northeast again, through similar faint shadings, to those visible diametrically opposite.

Closely around the following limb as it passed over the sun and until it was beyond the centre of the latter, was a delicate violet or reddish blue fringe, which made it difficult to detect the exact instant at which the solar spots emerged, and only one of them, whose occultation also had been noted—was observed with any degree of satisfaction. The fringe disappeared gradually. With the low magnifying power used, the only one sent with the comet-seeker, I was unable to detect inequalities on the lunar limb, and at 5*h*. 42*m*. 28*s*.2 it finally separated from that of the sun without other notable phenomenon.

A mist curtain had commenced rolling from the west before the end of the eclipse, and at 6*h*. 4*m*. there was not a portion of the sky visible in any direction. Two hours later the heat of the sun forced the screen upward in cumulous masses, leaving us with a warm and slightly humid atmosphere, until the regular northwest wind set in towards 9 o'clock.

For the purpose of introducing the observed occultation of one of the spots on the disc of the sun in its proper place, I recapitulate certain of the times already given in the text.

Times observed during the eclipse.

Immersion of spot	4*h*.	38*m*.	41*s*.3
First internal contact of limbs	4	47	29 .9
Second internal contact of limbs	4	49	25 .3
Duration of the total eclipse		1	55 .4
Emersion of spot	5	30	6 .4
End of the eclipse	5	42	28 .2

Observations for time and latitude were repeated during the day and evening, and on the 19th the instruments were repacked. Beneath the spot on which the comet-seeker stood a bottle, containing a suitable inscription, was buried, and a mound of stones three feet high erected thereupon. As the land can scarcely be regarded arable, it is not probable that this will be disturbed; but should it be, the bottle is beneath the reach of a plough, and the site is well known to persons at Steilacoom as well as by the occupants of the adjoining farm.

We returned to Fort Steilacoom on the 19th. On the 23d Mr. Mosman was instructed to rejoin his party at Gray's harbor, and Mr. Gilliss and myself embarked for San Francisco. Directing him, at the latter place, to report to Assistant Davidson, I left it on the 1st August and arrived at Washington on the 25th.

One word more. The occasion of our visit to Washington Territory was one of great interest to the highly accomplished officers of the army at Fort Steilacoom also, and their kind and intelligent counsel, their ever present readiness to facilitate every object of the expedition, and their most cordial hospitality to us, elicit our warmest and most grateful acknowledgments.

ACCOUNTS OF THE ECLIPSE FROM OTHERS.

From Mr. A. T. Mosman, U. S. Coast Survey.

Sky cloudless at 4 a. m., with a thick haze near the horizon. The first ray of light shone on Mount Rainier at 4*h*. 25*m*. At sunrise a bank of thin clouds rested on the (NE.) horizon, but the sun rose rapidly through them.

First internal contact at 1*h*. 21*m*. 52*s*.3 by siderial chronometer* (4*h*. 47*m*. 27*s*.6 M. T.) As the lune of sunlight decreased, the preceding limb of the moon appeared of a light green color, whilst the inner limb of the sun was of a rose color.† At the moment of contact the (sun's) limb was broken into bead-like spots, (see rough sketch,) which disappeared one after another, until the one at A was the last visible point of light. During this change the beads were of rainbow hue, green and red predominating.

After the eclipse became total I was unable to use my telescope, because there was not light enough to cast an image on the screen. On this account the time of the reappearance of light was marked by my naked eye, but as I was at the same time engaged in recording for Mr. Gilliss, the observation was doubtful. Time of reappearance, 1*h*. 22*m*. 39*s*.8, (4*h*. 48*m*. 15*s*.1.)‡

During the time of the totality I recorded the time of appearance of the protuberances, &c., for Mr. Gilliss, and therefore was unable to notice its phases minutely. The protuberances were of a golden hue, with a slight tinge of red. The corona was a compound of red, gold, and green. Its width appeared nearly equal to the radius of the moon, and it seemed to be formed by radial rays from the centre. Its width was constant and apparently concentric throughout the eclipse, with a slight wavy motion to and fro.

As the light increased I again followed the sun with the telescope, keeping the image upon the screen. End of the eclipse, 2*h*. 17*m*. 12*s*.5 by sidereal chronometer, (5*s*. 42*m*. 28*s*.8.)

The telescope used was Coast Survey reconnoitering telescope No. 10, of 4 feet focal length, 3 inches object glass, and fitted with a dark chamber at its eye-end, in which a screen of white paper was placed to receive the image of the sun. As the instrument had neither clamp nor tangent screws, and there were no means of giving a small motion to the telescope, either in a horizontal or a vertical direction, the image of the sun could not be kept in the centre of the field, and the plan first attempted for obtaining drawings of the sun was impracticable. Consequently, the rough sketches taken on the 15th and 17th were done by one person keeping the sun as nearly as possible to the centre of the field, whilst a second one rapidly drew the visible spots, their angles of position being fixed by the circles and lines of the diaphragm shadowed on the screen and corresponding with similar ones on paper held by the observer.

Soon after the end of the eclipse the sky became clouded over so that no drawing could be made of the spots.

A. T. MOSMAN.

From Mr. James Gilliss, U. S. Coast Survey.

I beg leave to submit the following remarks in relation to the solar eclipse of this morning:

The first rays of light, indicating the rising of the sun above the Cascade mountains, were of a pink color, and were visible at 4*h*. 22*m*. a. m.; but they were not of the same tint on the northeastern slope of Mount Rainier until 5 minutes afterward. The first cusp of the sun was seen at 4*h*. 30*m*. It was of a reddish color, and apparently had a wavy motion, which continued until the time of totality.

* At 1*h*. 13*m*. per No. 2113, the siderial (No. 311) showed 1*h*. 37*m*. 39*s*.1.

† Mr. Mosman stood with his back to the sun, and describes phases seen in the dark chamber.

‡ There is an evident error of at least one minute.

Preceding and during the latter event the atmosphere continued perfectly calm, but after the reappearance of the sunlight a light air could be perceived from the southward. This wind continued and gradually increased during several hours, though changing to the northward and westward by the afternoon.

I was prevented from observing any of the astronomical phenomena during the totality, because it had become so dark that the figures on the dial of the chronometer could no longer be distinguished by the observer using the telescope with the dark chamber, and I was unexpectedly called upon to note the time. The darkness had become so intense I feared for an instant that I should not be able to take up the beat of the chronometer, but my eyes became accustomed to the suddenly diminished light* after a few seconds, and I was enabled to recognize the division from which the seconds hand moved.

At 5*h.* 4*m.* a reddish cumulo-stratus cloud had formed in the SW., which lasted several minutes. At 5*h.* 14*m.* there was a distinct *mirage* over a part of the prairie ten or twelve feet lower than the spot we stood upon, and between us and the sun. It seemed to be about a mile distant, and the images continued several minutes. There was so much moisture in the air that it was with very great difficulty that the bulb of the air thermometer could be kept dry.

The outline of Mount Rainier was more distinct before the eclipse than it had been at any time during the preceding three weeks, clouds hitherto having prevented a perfect view near its base, as seen from camp above the fir belt to the SE.

A diagram showing the relative positions of the planets nearest the sun had been prepared, but in consequence of duties with the chronometer requiring all my attention during the brief time they might have been visible, I was prevented from looking for them.

JAMES GILLISS.

From H. A. Goldsborough, Esq.

We selected a position, early yesterday morning, clear of the garrison buildings, from whence a good horizon might be obtained, and where we were soon joined by nearly all the officers and ladies of the fort.

Presently the aurora gave warning of the immediate appearance of the sun, who gradually presented himself in perfect beauty and form, except to the NE., where the moon had already overlapped him probably one-eighth of his diameter. The progress of the moon's passage across the sun's disc was beautiful in the extreme, and at the period of totality there was the most gorgeous sight I ever witnessed.

The corona (apparently in width about the semi-diameter of the moon) gave forth brilliant scintillations of almost every hue, with that peculiar *étincelant* which we see in the pyrotechnic Catherine's wheels; yellow, blue, scarlet, rosy, and an indescribable approach to green, appeared to be intermingled, as if several sections of rainbows had been thrown promiscuously together.

Mount Rainier, 60 miles E. by S. of us, and some 15,000 feet high, was palled in the thickest gloom. The air was calm to me, and remained so during the entire transit; but I observed that the very considerable decrease of temperature was not *pari passu* or synchronous with the decrease of light, but that the latter was perceptibly in advance of the former.

A greyhound belonging to one of the ladies of our party attracted marked attention by the evident trepidation manifested, and particularly at the time of the greatest obscurity.

During the whole of the observations I used my Jumelle elliptical opera-glass—a very fine

* He evidently forgets that he held a lighted lantern in his hand.—J. M. G.

one, as you know—and though looking through it at the eclipse with all possible earnestness, there was not the slightest inconvenience to my eyes.

I congratulate you most sincerely that your journey from Washington has been crowned with such complete success.

H. A. GOLDSBOROUGH.

FORT STEILACOOM, *July* 19, 1860.

From Major G. O. Haller, U. S. A.

Agreeably to your request, I herewith submit a few items which came under my observation, or can be well authenticated, connected with the eclipse of the sun on the 18th instant.

A point on the southeastern shore of Wallace's (Anderson's?) island, in Puget sound, was selected by Captain George Henry Richards, commanding her Britannic Majesty's steamer Plumper, for observing the eclipse, and, by his invitation, I there became "a looker on."

From this station the sun was observed rising in unclouded majesty, but partially eclipsed. I found that the direct rays of the sun were endurable to my unpracticed eye. The waters of the sound were calm, smooth, and polished, and reflected the sun's light like a vast mirror, and during the total eclipse the corona was reflected by the water, giving a subdued and agreeable light to the eye, sufficient, I believe, for both reading instruments and writing notes.

When the sun was totally eclipsed I took a look around to observe the effect of the subdued light upon the scenery. To the southwest all nature appeared as if wrapt in night, feebly illuminated by a rising moon. Eastward I could see Mount Rainier, which was clearly within the limits of the moon's shadow, and visible as it often is in a pale moonlight; but not a single ray from the sun illuminated its snow-capped summit.

Several stars appeared above the sun, and bright crimson light was observed immediately about the edge of the moon, in three or four places; but all my faculties seemed to be too wrapped up in the undefinable and indescribable grandeur of the corona to give my attention to details.

The effect of this unusual appearance was very marked upon animals. The cattle in the barn-yard at Fort Nisqually were very much disturbed and greatly frightened. At Fort Steilacoom the dogs were observed to be terribly alarmed.

The view of the sun was uninterrupted until a few seconds after the two spots on the lower part of the disc had made their appearance, about which time a mist began to thicken the atmosphere, and a few seconds before the last contact the sun was completely obscured by clouds.

G. O. HALLER.

FORT STEILACOOM, *July* 21, 1860.

From Lieut. Thomas L. Casey, U. S. A.

In accordance with your request, that I should give you my recollections of such phenomena as I noticed in connection with the solar eclipse of the 18th instant, I would state that, thanks to a cloudless sky and a good position, I was enabled to have a fine view of this most wonderful occurrence.

As I was not provided with instruments, and merely observed the different phases of the eclipse through a piece of smoked glass, I shall only attempt to speak of the appearance as presented to me at totality.

Just before the light of the sun had entirely disappeared I had put aside my glass, and was

watching the fast-disappearing disc of that body, when I was startled by the sudden flashing out of the most beautiful fringe of light all around the disc of the moon. Its extent beyond the disc appeared to be about the lunar semi-diameter, and its edges were not well defined, but faded gradually away, the width of the fringe being greater in some than in other places. To me this corona had a peculiar greenish-yellow hue, which approached more nearly white light near the disc of the moon. At several places in it I noticed bright yellow flame-like coruscations, as though streaming through indentations in the edge of the disc. There were several of these, the largest one of which was at the upper left hand limb of the moon. The corona did not disappear on the reappearance of the sun, as it had flashed forth, but was perceptible a few seconds longer. In that time the whole disc of the moon was well defined, that part of it opposite to the uncovered part of the sun having a narrow band of light around it, giving it the appearance which is vulgarly described as "the old moon in the arms of the new."

The darkness upon the earth was not nearly so great as I had expected to experience; for I was enabled to distinguish the hands upon my watch, and to note the time, with the greatest ease. Although the sky was perfectly cloudless, that part of the heavens opposite to the sun presented a dark and murky appearance, as though a thunderstorm was rising in that quarter.

I greatly regret that I did not arrive here in time to see you before your departure for your observing station, in order that I might have heard from you a description of the eclipse of 1858, and thus, being better prepared for the appearances I was to observe, I could have noted them with more intelligence. As it is, the above are the features which impressed themselves upon my mind with the greatest force, and which, if they will be of any service to you, it gives me great pleasure to communicate.

THOS. LINCOLN CASEY.

FORT STEILACOOM, *July* 21, 1860.

From Dr. James B. Brown, U. S. A.

Hour.	THERMOMETER.		WIND.		Weather.		Remarks.
	Dry.	Wet.	Direction.	Force.			
h. m.	°	°					
4 0 a. m.	54	53	0	0	Fair.......	....	The thermometer, hygrometer, and weather continued without
30	54	53	E.	1	Fair.......	....	change from 4*h.* until 4*h.* 30*m.* a. m., when a scarcely percep-
45	54	53	E.	1	....	Cloudy....	tible breeze sprung up from the east, which had not sufficient
5 5	52	50	E.	1	....	Cloudy....	force to change the direction of the vane on the hospital build-
10	54	53	E.	1	Fair.......	....	ing, but affected a ribbon attached to a long pole very distinct-
15	53	52	E.	1	Fair.......	....	ly. The breeze continued from the same point from the time
20	53	51	E.	1	....	....	it was first noticed until 6 minutes after 6 o'clock, a m., with
25	52	51	E.	1	....	Cloudy....	the exception of about two minutes before the total eclipse,
30	52	51	E.	1	....	....	when the current appeared to come from the NE., and then
35	52	50	E.	1	....	....	changed again to east.
40	51	49	E.	1	....	....	The eclipse was first perceived here at 15 minutes before 5
45	51	49	E.	1	....	....	o'clock, and was total at 5 o'clock.* At a quarter past 5, one-
50	51	50	E.	1	....	Cloudy....	third of the sun was visible; at 5*h.* 25*m.*, two-thirds was visi-
55	51	50	E.	1	....	....	ble, dark clouds at the same time passing over the face of the
6 0	52	50	E.	1	....	....	sun, and the horizon almost black in the NE., and at 10
5	53	52	E.	1	....	....	minutes before 6 very dark clouds in the NE. and SW.
10	54	53	E.	2	....	.. ..	The sun was entirely visible at 5 minutes after 6 o'clock, and
15	55	53	E.	2	....	....	the clouds cleared from NW. immediately after.

* Dr. Brown's time-keeper was evidently at least 12¼*m.* slow.—J. M. G.

APPENDIX No. 23.

Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, *and* 1845. *Part II.—Investigation of the solar-diurnal variation in the magnetic declination, and its annnal inequality. By A. D. Bache, LL.D.*

Having discussed, in Part I, the eleven year period in the amplitude of the solar-diurnal variation, as well as in the disturbances of the magnetic declination, I now proceed to the analysis of the annual inequality of the solar-diurnal variation.

To obviate the difficulty which would occur in cases of months of unusual disturbance if the crude observations were used, the normals or means freed from the disturbances have been employed in the discussion. This mode of proceeding not only obviates the necessity for rejecting the observations for particular months, but brings out the most consistent results which the observations can furnish for both diurnal and annual variation. It is the course adopted by General Sabine in the third volume of his discussion of the Toronto observations.*

Returning, then, to the hourly normals, they are rearranged in the tables which follow according to the different months of the year. The normals for 1840 are corrected for the index error by the addition of 93.3 scale divisions. All corrections for referring the partial monthly readings to the annual mean are, of course, omitted.

Hourly declination—normals for January.†

[Observations 19¼ minutes later than indicated. Value of one scale division 0′.453. Increase of scale divisions corresponds to a decrease of westerly declination.]

Year.	0*h*.	1*h*.	2*h*.	3*h*.	4*h*.	5*h*.	6*h*.	7*h*.	8*h*.	9*h*.	10*h*.	11*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
1840	....	....	....	....	....	....	....	....	....	....	....	....
1841	579.3	....	577.0	....	578.6	....	576.9	....	580.7	....	581.9	....
1842	564.3	....	563.8	....	565.3	....	565.9	....	570.9	....	566.4	....
1843	....	....	....	....	....	....	....	....	....	....	....	....
1844	558.6	558.2	558.4	559.2	558.9	558.8	559.7	561.2	562.9	563.3	559.1	555.9
1845	530.9	531.3	531.1	531.5	533.0	531.6	532.9	535.2	535.8	533.8	530.2	526.7
Mean‡	558.28	....	557.57	....	558.95	....	558.85	....	562.57	....	559.40	....
Same referred to its mean epoch§	565.25	564.80	564.35	565.62	565.70	564.66	565.47	567.74	569.27	569.51	566.65	561.88

TABLE—Continued.

Year.	Noon.	13*h*.	14*h*.	15*h*.	16*h*.	17*h*.	18*h*.	19*h*.	20*h*.	21*h*.	22*h*.	23*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
1840	....	....	....	....	....	....	....	....	....	....	....	....
1841	570.0	....	568.8	....	570.3	....	574.2	....	578.0	....	580.1	....
1842	556.7	....	556.0	....	562.9	....	563.2	....	566.1	....	567.8	....
1843	....	....	555.4	....	....	....	....	....	....	....	....	....
1844	552.9	552.4	553.2	554.1	556.3	556.9	557.8	559.2	559.5	560.9	560.8	559.6
1845	524.2	525.2	526.2	528.0	530.1	531.8	532.7	532.8	533.3	533.0	532.4	532.0
Mean‡	550.95	....	551.92	....	554.90	....	556.97	....	559.22	....	560.27	....
Same referred to its mean epoch§	557.72	557.31	557.55	558.97	561.20	562.41	563.38	564.82	565.90	567.00	567.20	566.35

* Table LXVI of this volume exhibits the solar diurnal variation of the declination after the separation and omission of the larger disturbances; whereas table VII of the preceding volume, similar in form, differs from it, the latter being derived from all the observations including the disturbances.

† The hours refer to mean local time, reckoned from midnight to 24 hours.

‡ The mean given is the single mean of the four readings, and at 14*h*. of five readings, and is here inserted for comparison with the corrected mean in the line below, which would have been obtained if there had been no omissions in the observations.

§ To obtain the normals referring to January of the mean year, the readings for the defective years, 1840 and 1843, have been interpolated in the following manner: 1. *For the even hours.* The normals for any two consecutive years differ simply by the annual effect of the secular change which may be regarded as uniform, when the same hours and months are compared as in the present case. The values derived from the comparison of the

Hourly declination—normals for February.

[Observations 19¼m. later than indicated. One division of scale 0′.453.]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	....	....	....	....	....	....	....	....	....	....	....	....
1841	575.0	....	573.2	....	575.6	....	577.8	....	582.1	....	579.5	....
1842	564.5	....	564.3	....	563.8	....	565.2	....	567.8	....	565.5	....
1843	....	....	....	....	....	....	....	....	....	....	....	....
1844	559.1	558.5	559.1	559.2	559.9	561.1	560.8	562.1	562.2	560.7	557.3	554.5
1845	531.6	531.1	531.0	532.4	532.3	533.1	534.7	535.9	535.7	535.4	533.0	528.6
Mean	557.55	....	556.90	....	557.90	....	559.62	....	561.95	....	558.82	....
Same referred to its mean epoch	563.88	563.10	563.13	563.90	564.23	565.25	565.93	567.88	568.53	567.97	565.42	561.47

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	....	....	....	....	....	....	....	....	....	....	....	....
1841	569.5	....	566.0	....	569.5	....	572.4	....	574.4	....	575.8	....
1842	558.2	....	559.9	....	558.0	....	561.9	....	565.3	....	565.5	....
1843	....	....	555.9	....	....	....	....	....	....	....	....	....
1844	551.1	551.1	553 0	554.7	556 4	556.6	557.6	558.4	559.9	559.4	560.1	559.0
1845	524.4	523.0	525.3	527.5	529.7	530.4	532.4	531.3	533.6	534.4	532.3	531.9
Mean	550.80	....	552.02	....	553.40	....	556.07	....	558.30	....	558.42	....
Same referred to its mean epoch	557.33	555 85	557.17	558.30	559.43	560 25	562.13	562.25	564.42	565.02	564.77	564.00

Hourly declination—normals for March.

[Observations 19¼m. later than indicated. One division of scale 0′.453.]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	....	....	....	....	....	....	....	....	....	....	....	....
1841	577.1	....	577.6	....	580.9	....	582.9	....	586.8	....	578.9	....
1842	564.8	....	564.1	....	565.4	....	566.1	....	571.8	....	565.9	....
1843	....	....	....	....	....	....	....	....	....	....	....	....
1844	558.0	559.0	559.2	557.9	559.8	560.2	561.3	563.6	564.8	564.1	560.3	554.9
1845	532.9	532.7	533.7	533.6	535.0	533.9	536.0	538.8	539.4	538.6	534.5	529.4
Mean	558.20	....	558.65	....	560.27	....	561.58	....	565.70	....	559.90	....
Same referred to its mean epoch	565.60	565.72	566.03	565.75	567.82	567.53	569.20	572.11	573.37	571.95	567.32	562.02

several months of any two years differ, however, by the accidental errors of the observations; thus taking the difference in the normals for 1840 and 1841, we obtain for the several months the values—

	d.
June	+15.7
July	20.5
August	18.5
September	21.9
October	12.7
November	17.5
December	20 0
Mean	16.86

which mean corresponds exactly to the difference of the constant terms in part I, for 1840 and 1841. By adding, therefore, 16.9 scale divisions to the normals for 1841, we obtain interpolated values for 1840. The values from January to May, 1840, were thus supplied. The normals for 1843 were supplied in a different manner by making use of the readings at 2 p. m., which were taken for the purpose of keeping up the continuity of the series. Subtracting 0.6 scale divisions from the hourly readings of 1842, we obtain those for 1843, this being the difference at 14h.; in like manner adding 2.2 scale divisions to the readings of 1844, we obtain a second value for the normals of 1843; the mean of these two independent determinations has been used in supplying the readings for 1843. The normals for 1840 and 1843 being thus supplied, the figures in the last line of the preceding table are obtained by simply taking the mean of the six readings at each even hour. 2 *For the odd hours.* The difference in the mean readings for any given odd hour, in 1844 and 1845, from the two adjacent even hours, was applied to the normals of these hours, and the mean taken as the normal of the intermediate odd hour; thus the mean reading at noon of 1844 and 1845, is 538 55 at 13h. 538.80, difference +0.25, which, added to the noon normal 557.72, gives 557.97, and in like manner by comparison with hour fourteen, the correction to its normal is —0.90, and the normal for 13h. becomes 556.65; the mean of the two results 557.31 is the resulting normal for this hour, as given in the table.

The same principle of interpolation was applied throughout the tables. Due attention must be paid to the deductions for the unequal weight of the normals, for the even and odd hours, these weights being generally as 5 : 2, or proportional to the number of separate readings. The application of a nearly constant quantity to refer means from a defective number of years to the mean epoch of all the years, is not of much consequence in regard to the diurnal and annual irregularities which depend mainly on differences of readings, but it is essential that no changes should have occurred in the zero of the scale during any interval under discussion.

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	...	...	...	...	...	...	...	...	...	...	...	...
1841	569.4	...	567.7	...	571.8	...	576.4	...	577.4	...	577.7	...
1842	555.6	...	553.9	...	556.4	...	560.3	...	564.5	...	564.9	...
1843	...	...	557.2	...	...	...	...	...	...	...	...	...
1844	550.6	549.4	549.6	551.7	553.0	555.2	556.6	558.0	558.4	558 2	558.6	559.7
1845	524.8	522.5	522.8	524.8	527.8	529.7	531.6	533.0	533.0	533.8	533.5	534.0
Mean	550.10	...	550.24	...	552.25	...	556.22	...	508.32	...	558.67	...
Same referred to its mean epoch	557.52	555.75	555.97	557.75	559.63	561.85	563.68	565.31	565.75	566 04	566.08	566.94

Hourly declination—normals for April.

[Observations 19¼m. later than indicated. One division of scale 0′.453.]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	...	...	...	...	...	...	...	...	...	...	...	...
1841	580.0	...	581.9	...	582.9	...	585.6	...	587.6	...	579.4	...
1842	563.3	...	565.4	...	566.1	...	568.5	...	569.7	...	563.6	...
1843	569.7	...	570.0	...	571.0	...	574.7	...	576.2	...	566.2	...
1844	556.6	557.0	557.2	556.9	557.5	558.4	561.7	558.5	564.4	561.8	557.1	552.0
1845	529.1	528.8	529.0	529 2	529.8	531.7	534.0	535.6	537.5	535.4	528.5	522.5
Mean	559.74	...	560.70	...	561.46	...	564.90	...	567.08	...	558.96	...
Same referred to its mean epoch	565.93	566.42	567.05	567.12	567.85	568.31	571.17	569.90	573.32	570.98	565.18	559.76

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	...	...	...	...	...	...	...	...	...	...	...	...
1841	568.8	...	566.1	...	571.7	...	576.9	...	578.0	...	579.1	...
1842	554.0	...	552.5	...	555.1	...	560.6	...	561.3	...	563.0	...
1843	557.8	...	555.7	...	562.6	...	564.8	...	568.5	...	568.7	...
1844	547.4	545.7	546.2	547.6	549.6	553.4	553 4	553.8	556.2	555.1	555.7	559.3
1845	517.8	513.9	514.0	517 2	521.5	525.8	527.8	527.9	528.1	528.5	528.0	529.4
Mean	549.16	...	546.90	...	552.10	...	556.70	...	558.42	...	558.90	...
Same referred to its mean epoch	555.25	552.24	552.92	555.13	558.18	562.05	562.88	563.16	564.50	564.59	565.08	567.50

Hourly declination—normals for May.

[Observations 19¼ minutes later than indicated. One division of scale 0′.453.]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	...	...	...	...	...	...	...	...	...	...	...	...
1841	579.1	...	579.8	...	581.9	...	587.4	...	589.1	...	578.6	...
1842	563.3	...	564.3	...	566.0	...	571.2	...	569.5	...	560.0	...
1843	567.0	...	567.3	...	569.6	...	574.6	...	575.6	...	565.7	...
1844	548.4	548.7	547.8	547.0	549.3	552.5	555.8	556.8	555.1	552.3	546.7	542.2
1845	529.9	531.3	529 7	531.7	533.2	536 3	539.3	541.9	540.7	536.0	528.0	522.6
Mean	557.54	...	557.78	...	560.00	...	565.66	...	566.00	...	555.80	...
Same referred to its mean epoch	563.95	565.16	564.27	564.72	566 47	569.28	572.10	574.01	572 67	569.07	532.42	557.72

TABLE—Continued.

Year.	Noon.	13*h*.	14*h*.	15*h*.	16*h*.	17*h*.	18*h*.	19*h*.	20*h*.	21*h*.	22*h*.	23*h*.
	d.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.
1840	....	....	....	....	....	....	....	....	....	....	....	....
1841	569.4	....	567.9	....	573.6	....	577.4	....	578.5	....	580.1	....
1842	552.6	....	552.3	....	557 7	....	560.8	....	561.8	....	562.3	....
1843	556.0	....	556.2	....	562.2	....	566.4	....	566.9	....	567.3	....
1844	538.3	535.8	536.5	538.9	542.1	545.1	545.2	546.5	546.3	547.3	547.3	547.8
1845	517.1	516.8	518.9	522.1	526.7	529.3	529.6	530.4	529.7	530.3	530.5	530.3
Mean	546.68	....	546 36	....	552.46	....	555.88	....	556 64	....	557.50	....
Same referred to its mean epoch	553.28	551.62	552.77	555.23	558 80	561.94	562.28	563.44	563.10	563.94	564.09	564.04

Hourly declination—normals for June.

[Observations 19¼ minutes later than indicated. One division of scale 0′.453.]

Year.	0*h*.	1*h*.	2*h*.	3*h*.	4*h*.	5*h*.	6*h*.	7*h*.	8*h*.	9*h*.	10*h*.	11*h*.
	d.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.
1840	587.7	....	588.3	....	590.8	....	597.3	....	596.0	....	587.1	....
1841	571.7	....	572.2	....	574.7	....	583.3	....	582.6	....	571.1	....
1842	564.6	....	563.7	....	567.2	....	573.7	....	573.0	....	565.2	....
1843	566.0	....	565.6	....	568.4	....	574.1	....	573.9	....	564.8	....
1844	548.7	549.0	549.3	549.1	551.6	553.9	557.6	659.1	558.2	554.3	547.9	541.8
1845	531.5	531.7	531.6	532.0	534.8	537.9	541.9	543.5	542.5	538.6	532.2	524.9
Mean	561.70	....	561.78	....	564.58	....	571.32	....	571.03	....	561.38	....
Same referred to its mean epoch	....	561.81	....	561.91	....	567.38	....	572.42	....	567.46	....	555.22

TABLE—Continued.

Year.	Noon.	13*h*.	14*h*.	15*h*.	16*h*.	17*h*.	18*h*.	19*h*.	20*h*.	21*h*.	22*h*.	23*h*.
	d.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.
1840	578.8	....	576.7	....	581.2	....	586.1	....	585.8	....	586.9	....
1841	561.6	....	560.3	....	565 0	....	570.1	....	570.9	....	570.8	....
1842	555.1	....	552.5	....	558.3	....	561.8	....	563.7	....	564.1	....
1843	556.4	....	556 0	....	561.1	....	564.3	....	564.0	....	565.6	....
1844	537.4	535.0	537.3	540.0	542.4	545.2	545.6	546.2	546.5	546.8	548.0	548.5
1845	521.3	519.6	520.0	522.1	525.4	528.9	530.3	530.7	530.1	530.7	530.3	531.4
Mean	551.77	....	550.47	....	555.57	....	559.70	....	560.17	....	560.95	....
Same referred to its mean epoch	....	549.42	....	552.80	....	558.56	....	560 26	....	560.58	....	561.65

Hourly declination—normals for July.

[Observations 19¼ minutes later than indicated. One division of scale, 0′.453.]

Year.	0*h*.	1*h*.	2*h*.	3*h*.	4*h*.	5*h*.	6*h*.	7*h*.	8*h*.	9*h*.	10*h*.	11*h*.
	d.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.	*d*.
1840	590.6	....	590.5	....	592 2	....	598.0	....	598.8	....	588.7	....
1841	569.9	....	568.5	....	571.6	....	578.4	....	581.2	....	571.8	....
1842	566.0	....	566.0	....	568.4	....	576.6	....	576.4	....	565.8	....
1843	566.9	....	565.9	....	568.2	....	574.2	....	574.6	....	564.5	....
1844	549.0	550.5	548.4	549.4	551.0	554.3	556.9	559 8	558.6	554.8	548.0	540.8
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	568.48	....	567.86	....	570.28	....	576.82	....	577.92	....	567.76	....
Same referred to its mean epoch	561.77	563.26	561.15	562.07	563.60	567.16	570.02	572.67	571.23	567.61	561.00	553.47

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	577.8	....	577.3	....	582.0	....	586 6	....	588 8	....	589.6	....
1841	558.9	....	557.3	....	562.3	....	567.2	....	568.8	....	568.6	....
1842	556.3	....	553.8	....	558.5	....	562.4	....	564.2	....	567.1	....
1843	555.1	....	554.1	....	559.5	....	563 6	....	563.8	....	565.6	....
1844	538.3	535.5	536.3	538.8	541.9	544.5	545.8	546.2	546.6	547.4	548.8	549.3
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	557.28	....	555.76	....	560.84	....	565.12	....	566.44	....	567.94	....
Same referred to its mean epoch	550.65	548.05	549.05	551.33	554.22	556.98	558.43	559.05	559.67	560.18	561.28	561.97

Hourly declination—normals for August.

[Observations 19¼ minutes later than indicated. One division of scale, 0′.453.]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	588.6	589.0	589.0	....	592.1	....	599.7	....	602.4	....	582.7	....
1841	568.4	....	570.3	....	571.6	....	580.1	....	583.9	....	568.9	....
1842	564.8	....	566.0	....	568.5	....	573.7	....	575.0	....	560.0	....
1843	564.2	....	564.5	....	567.2	....	573.5	....	572.7	....	560.5	....
1844	548.6	547.8	547.3	547.4	550.9	552 4	557.5	560.3	558.2	551.8	543.3	536.4
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	566.92	....	567.42	....	570.06	....	576.90	....	578.44	....	563.08	....
Same referred to its mean epoch	560.40	559.85	560.60	560.80	563.40	565.00	570.20	573.35	571.60	565.01	556.32	549.14

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	573.8	....	575.2	....	581.5	....	586.5	....	588.2	....	589.4	....
1841	558.3	....	556.9	....	564.0	....	566.8	....	568.6	... .	568.9	....
1842	552.3	....	553.7	....	561 5	....	562.2	....	564.1	....	564.5	....
1843	555.1	....	554.6	....	561.2	....	563.6	....	562.3	....	564.2	....
1844	531.8	532.0	534.3	538.7	542.1	544 3	546.0	546.5	546.7	546.6	547.8	547.7
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	554.26	....	554.94	....	562.06	....	565.02	....	565.98	....	566.96	....
Same referred to its mean epoch	547.05	546.49	548.03	552.15	555.27	557.12	558.38	558.99	559.30	559.15	560.30	559.85

Hourly declination—normals for September.

[Observations 19¼ minutes later than indicated. One division of scale, 0′.453]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	585.8	....	588.5	....	590.2	....	596.5	....	595.8	....	584.1	....
1841	565.1	....	564.5	....	565 5	....	569.4	....	571.1	....	564.1	....
1842	567.4	....	567.8	....	570.0	....	576.8	....	574.9	....	561.2	....
1843	560.4	....	560.4	....	560.3	....	565.7	....	566.6	....	554.6	....
1844	543.3	543.1	544.1	546.0	546.5	547.1	550.0	552.9	552.4	545.8	538.3	532.5
1845	....	....	....	....	....	....	....	....	....	....	....	.. ..
Mean	564.40	....	565.06	....	566.50	....	571.68	....	572 16	....	560.46	....
Same referred to its mean epoch	557.42	557.16	558.10	559.60	559.70	561.00	564.60	566.70	565.40	559.80	553.30	47.47

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	570.6	....	572.8	....	581.7	....	583.2	....	586.6	....	585.9	....
1841	553.6	....	554.5	....	559.5	....	562.9	....	563.8	....	564.0	....
1842	556.0	....	555.4	....	562.0	....	565.7	....	566.7	....	566.6	....
1843	547.5	....	550.5	....	556.8	....	558.0	....	560.0	....	558.7	....
1844	529.3	530.0	534.1	538.3	539.4	541.9	542.4	541.9	543.0	544.6	543.7	543.3
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	551.40	....	553.46	....	559.88	....	562.44	....	564.02	....	563.78	....
Same referred to its mean epoch	544.25	543.81	546.77	551.44	553.00	555.31	555.63	556.04	557.05	558.26	556.97	557.00

Hourly declination—normals for October.

[Observations 19¼ minutes later than indicated. One division of scale, 0′.453.]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	585.8	....	583.7	....	584.4	....	582.4	....	582.5	....	577.4	....
1841	566.8	....	566.3	....	565.5	....	567.6	....	569.4	....	568.2	....
1842	563.1	....	563.1	....	564.4	....	566.0	....	568.8	....	561.0	....
1843	559.6	560.2	559.6	559.1	559.9	560.6	562.1	565.1	566.0	565.0	560.8	556.5
1844	545.1	545.3	544.2	546.1	545.8	544.4	548.6	550.9	551.5	548.7	545.3	540.8
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	564.06	....	563.38	....	564.00	....	565.34	....	567.64	....	563.14	....
Same referred to its mean epoch	557.45	557.71	556.72	557.33	557.50	556.67	559.08	561.23	561.48	560.04	556.70	552.36

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	571.7	....	570.6	....	575.2	....	579.6	....	579.0	....	586.4	....
1841	564.0	....	562.3	....	564.7	....	573.5	....	568.6	....	569.3	....
1842	556.0	....	555.0	....	558.2	....	564.3	....	565.0	....	565.3	....
1843	553.6	552.6	552.7	554.2	556.2	557.0	558.2	559.7	560.1	561.1	559.7	560.7
1844	541.1	539.5	541.4	544.0	545.7	545.4	545.6	545.0	544.9	544.6	544.5	544.6
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	557.28	....	556.40	....	560.00	....	564.24	....	563.56	....	565.04	....
Same referred to its mean epoch	551.12	549.62	550.43	552.39	554.15	555.68	557.67	557.47	556.98	558.12	558.15	558.92

Hourly declination—normals for November.

[Observations 19¼ minutes later than indicated. One division of scale, 0′.453.]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	574.4	....	573.9	....	576.2	....	577.0	....	579.7	....	575.0	....
1841	557.2	....	558.5	....	558.5	....	557.6	....	561.7	....	557.1	....
1842	564.2	....	563.8	....	565.6	....	566.9	....	569.2	....	563.3	....
1843	556.3	556.7	556.6	556.6	557.4	557.4	559.1	561.8	561.3	560.1	556.2	552.6
1844	546.8	546.8	548.3	548.6	547.4	548.5	551 5	549.2	548.4	547.9	546.2	542.8
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	559.78	....	560.22	....	561.02	....	562.42	....	564.06	....	559.56	....
Same referred to its mean epoch	554.15	554.21	554.77	555.20	555.28	555.30	557.13	557.98	557.98	556.90	553.87	550.00

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	567.5	....	565.8	....	570 8	....	574.1	....	576.9	....	576.0	....
1841	551.8	....	549.9	....	553.4	....	554.9	....	558.0	....	558.6	....
1842	556.6	....	557.3	....	561.2	....	564.0	....	565.5	....	565.0	....
1843	550.4	550.0	551.1	552.6	553 8	554.9	556.3	557.5	557.5	557.7	557.3	557.4
1844	542 8	541.7	544.5	546.1	545.6	547.9	548.8	548.2	548.3	549.6	548.0	548.0
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	553.82	....	553.72	....	556.96	....	559.62	....	561.24	....	560.98	....
Same referred to its mean epoch	548.52	547.32	548.72	550.76	551.60	553.25	554.35	555.26	555.62	556.36	555.35	555.35

Hourly declination—normals for December.

[Observations 19½ minutes later than indicated. One division of scale, 0′.453.]

Year.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	571.2	....	568.5	....	573.1	....	572.8	....	573.8	....	573.9	....
1841	560.1	....	559.3	....	560.5	....	559.6	....	560.1	....	558.1	....
1842	561.7	....	560.7	....	562.1	....	562.7	....	565.5	....	564.2	....
1843	559.0	558.1	557.4	558.2	557.8	558.8	560.0	560.8	561.2	561.9	559.9	556.7
1844	536.1	535.8	535.4	535.9	536.8	537.3	537.2	536.8	537.9	539.3	536.1	532.9
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	557.62	....	556.76	....	558.96	....	558.46	....	559.70	....	558.44	....
Same referred to its mean epoch	550.57	549.92	549.32	550.38	551.05	551.35	551.45	551.75	552.60	553.75	551.25	547.78

TABLE—Continued.

Year.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1840	564.0	....	564.9	....	566.0	....	571.8	....	572.3	....	574.5	....
1841	552.9	....	551.7	....	555.8	....	559.6	....	563.3	....	561.6	....
1842	556.6	....	556.2	....	560.1	....	562.0	....	563 5	....	563.8	....
1843	552.9	551.4	550.9	553.1	554.6	557.5	558.2	558.9	559.6	560.0	559.9	559.5
1844	530.6	529.3	529.4	532.1	533.2	534.8	535.9	537.0	536.8	537.4	537.8	537.1
1845	....	....	....	....	....	....	....	....	....	....	....	....
Mean	551.40	....	550.62	....	553.94	....	557.50	....	559.10	....	559.52	....
Same referred to its mean epoch	544.47	543.45	543.62	546.35	547.02	549.40	550.43	551.50	551.92	552.35	552.43	551.60

The following table contains the recapitulation of the monthly normals for each hour of the day, and for the mean epoch 1842.0 to 1843.0, and forms the basis for the discussion of the diurnal variation and its annual inequality. The table exhibits at one view the mean hourly readings for each month, unaffected by the larger disturbances:

Monthly declination-normals for each hour of the day, and for the mean epoch of 1842-'43.

[Increasing scale divisions denote an easterly movement of the north end of the magnet. The readings belong to an hour 19¼ minutes later than indicated by the figures at the head of the columns. Value of a scale division, 0'.453. Readings derived from five years' observations between 1840 and 1845.]

Mean epoch—1842-'43.	PHILADELPHIA MEAN TIME.											
	0*h*.	1*h*.	2*h*.	3*h*.	4*h*.	5*h*.	6*h*.	7*h*.	8*h*.	9*h*.	10*h*.	11*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
January	565.25	564.80	564.35	565.62	565.70	564.66	565.47	567.74	569.27	569.51	566.65	561.88
February	563.88	563.10	563.13	563 90	564.23	565.25	565.93	567.88	568.53	567.97	565.42	561.47
March	565.60	565.72	566.03	565.75	567.82	567.53	569.20	572.11	573 37	571.95	567.32	562.02
April	565.93	566.42	567.05	567.12	567.85	568.31	571.17	569.90	573.32	570.98	565.18	559.76
May	563 95	565.16	564.27	564.72	566.47	569.28	572.10	574.01	572 67	569.07	562.42	557.72
June	561.70	561.81	561 78	561.91	564.58	567.38	571.32	572.42	571.03	567.46	561.38	555.22
July	561.77	563.26	561.15	562.07	563.60	567.16	570.02	572.67	571.23	567.61	561.00	553.47
August	560.40	559.85	560.60	560.80	563.40	565.00	570.20	573.35	571.60	565.01	556.32	549.14
September	557 42	557.16	558.10	559.60	559.70	561.00	564.60	566 70	565.40	559 80	553.30	547.47
October	557.45	557.71	556.72	557.33	557.50	556.67	559.08	561.23	561.48	560.04	556.70	552.36
November	554.15	554.21	554.77	555.20	555.28	555.30	557.13	557.98	557.98	556.90	553.87	550.00
December	550.57	549.92	549.32	550.38	551 05	551.35	551.45	551.75	552.60	553.75	551.25	547.78

Monthly declination-normals, &c.—Continued.

Mean epoch—1842-'43.	PHILADELPHIA MEAN TIME.												
	Noon.	13*h*.	14*h*.	15*h*.	16*h*.	17*h*.	18*h*.	19*h*.	20*h*.	21*h*.	22*h*.	23*h*.	Mean.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
January	557.72	557.31	557.55	558.97	561.20	562.41	563.38	564.82	565.90	567.00	567.20	566.35	564.20
February	557.33	555.85	557.17	558.30	559.43	560.25	562.13	562.25	564.42	565 02	564.77	564.00	562.98
March	557 52	555.75	555.97	557.75	559.63	561.85	563.68	565.31	565.75	566.04	566.08	566.94	564.86
April	555.25	552.54	552.92	555.13	558.18	562.05	562.88	563.16	564.50	564.59	565.08	567.50	564.03
May	553.28	551.62	552 77	555.23	558.80	561.94	562.28	563.44	563.10	563.94	564.09	564.04	563.18
June	551.77	549.42	550.47	552.80	555.57	558.76	559.70	560.26	560.17	560 58	560.95	561.65	560.84
July	550.65	548.05	549.05	551.33	554.22	556.98	558.43	559.05	559.67	560.18	561.28	561.97	560.24
August	547.05	546.49	548.03	552.15	555.27	557.12	558.38	558.99	559.30	559.15	560.30	559.85	559.07
September	544.25	543.81	546.77	551.44	553.00	555.31	555.63	556.04	557.05	558.26	556.97	557.00	556.07
October	551.12	549.62	550.43	552.39	554.15	555.68	557.67	557.47	556.98	558.12	558 15	558.22	556.43
November	548.52	547.32	548.72	550.76	551.60	553.25	554.35	555.26	555.62	556.36	555.35	555.35	553.97
December	544.47	543.45	543.62	546.35	547.02	549.40	550.43	551.50	551.92	552.35	552.43	551.60	549.82
Mean	....	....	....	....	....	....	....	....	....	....	....	....	559.64

This table shows plainly the relation of the mean hourly position of the magnet of each month to its general mean position after the separation of the larger disturbances, and also, by running the eye along any horizontal line, the solar diurnal variation for each month. It does not, however, show distinctly the annual inequality, on account of the changes in the numbers from the secular change. To eliminate the effect of this change, each hourly normal has been compared, in the following table, with the corresponding mean monthly value, as given in the last right hand column, the sign + indicating a westerly deviation, and — an easterly deviation* of the north end of the magnet from the mean monthly position. The scale divisions have been converted into minutes of arc.

* The sign plus (+) being generally taken to signify west declination, it has been retained to indicate a movement of the north end of the magnet to the west.

Table of the solar-diurnal variation of the magnetic declination for each month of the year, showing the annual inequality.

[Observations 19½ minutes later than indicated in the heading.]

Mean epoch—1842–'43.	PHILADELPHIA MEAN TIME.											
	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	'	'	'	'	'	'	'	'	'	'	'	'
January	−0.47	−0.27	−0.07	−0.64	−0.68	−0.21	−0.57	−1.61	−2.29	−2.40	−1.11	+1.06
February	−0.41	−0.06	−0.07	−0.42	−0.56	−1.03	−1.34	−2.22	−2.51	−2.26	−1.11	+0.68
March	−0.34	−0.39	−0.53	−0.40	−1.35	−1.21	−1.97	−3 28	−3.85	−3.21	−1.12	+1.29
April	−0.86	−1.09	−1.37	−1.40	−1.73	−1.94	−3.24	−2.65	−4.21	−3.15	−0.50	+1.93
May	−0.35	−0.90	−0.49	−0.70	−1.49	−2.77	−4.04	−4.90	−4.30	−2.66	+0.35	+2.47
June	−0.39	−0.44	−0.43	−0.48	−1.70	−2.97	−4.75	−5.25	−4.62	−3.00	−0.25	+2.54
July	−0.68	−1.37	−0.41	−0.82	−1.53	−3.18	−4.44	−5.63	−4.98	−3.34	−0.35	+3.07
August	−0.60	−0.36	−0.69	−0.78	−1.96	−2.68	−5.03	−6.47	−5.68	−2.69	+1 25	+4.50
September	−0.61	−0.49	−0.92	−1.60	−1.64	−2.23	−3.86	−4.81	−4.23	−1.69	+1.26	+3.89
October	−0.46	−0.58	−0.13	−0.41	−0.48	−0.10	−1.20	−2.17	−2 28	−1.63	−0.12	+1.84
November	−0.09	−0.11	−0.36	−0.55	−0.59	−0.60	−1.44	−1.81	−1.61	−1.33	+0.05	+1.80
December	−0.34	−0.05	+0.23	−0.26	−0.55	−0.69	−0.73	−0.87	−1.27	−1.78	−0.64	+0.93
Summer	−0.58	−0.78	−0.72	−0.96	−1.68	−2.63	−4.23	−4.95	−4.67	−2.76	+0.29	+3.07
Winter	−0.35	−0.24	−0.16	−0.45	−0.70	−0.64	−1 22	−1.99	−2.33	−2.10	−0.67	+1.27
Year	−0 47	−0 51	−0.44	−0.71	−1.19	−1.64	−2 72	−3.47	−3.50	−2.43	−0.19	+2.17

Table of the solar-diurnal variation of the magnetic declination, &c.—Continued.

Mean epoch—1842–'43.	PHILADELPHIA MEAN TIME.											
	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	'	'	'	'	'	'	'	'	'	'	'	'
January	+2.94	+3.12	+3.01	+2.36	+1.36	+0.81	+0.37	−0.28	−0.77	−1.27	−1.36	−0.98
February	+2.55	+3.23	+2.62	+2.12	+1.61	+1.24	+0.38	+0.33	−0.65	−0.93	−0.81	−0.46
March	+3.33	+4.13	+3.02	+3 22	+2.36	+1.36	+0.53	−0.20	−0.40	−0.54	−0.55	−0.95
April	+3.98	+5.20	+5.02	+4.03	+2.64	+0.90	+0.52	+0.39	−0.21	−0.26	−0.47	−1.57
May	+4.49	+5.24	+4.71	+3.60	+1.99	+0 56	+0.41	−0.12	+0.04	−0.35	−0.41	−0.39
June	+4.11	+5.16	+4.70	+3.64	+2.38	+0.95	+0 51	+0.27	+0.30	+0.12	−0.05	−0.36
July	+4.85	+5.53	+5.07	+4.03	+2 73	+1.47	+0.81	+0.53	+0.26	+0.03	−0.47	−0.78
August	+5.45	+5.71	+5.00	+3.14	+1.72	+0.88	+0.32	+0.04	−0.10	−0.04	−0.56	−0.36
September	+5.35	+5.56	+4.17	+2.09	+1.39	+0.35	+0.20	+0.01	−0.45	−1.00	−0.41	−0.42
October	+2.40	+3.08	+2.72	+1.83	+1.04	+0.35	−0.56	−0.47	−0.25	−0.76	−0.78	−0 81
November	+2 46	+3.01	+2.37	+1.45	+1.08	+0.33	−0.18	−0 59	−0.74	−1.09	−0.63	−0.63
December	+2.42	+2.89	+2.81	+1.57	+1.27	+0.19	−0.27	−0.76	−0.96	−1.15	−1.18	−0.81
Summer	+4.62	+5.40	+4.78	+3.42	+2.14	+0.85	+0.46	+0.19	−0.03	−0.25	−0.40	−0.65
Winter	+2.68	+3.24	+2.76	+2.09	+1.46	+0.71	+0 05	−0.33	−0.63	−0.95	−0.88	−0.77
Year	+3.65	+4.32	+3.77	+2.76	+1.80	+0.78	+0.25	−0.07	−0.33	−0.60	−0.64	−0.71

The distinctive features of the above table are next to be considered analytically as well as graphically. The inequality in the diurnal variation is most conspicuous when the tabular numbers in the horizontal lines for the months of February and August are compared. The annual variation appears plainest by carrying the eye over the vertical column at the hours 6 or 7 a. m. The annual variation depends on the earth's position in its orbit, the diurnal variation being subject to an inequality depending on the sun's declination. The diurnal range is

greater when the sun has north declination, and smaller when south declination, the phenomenon passing from one state to the other about the time of the equinoxes.

To show the diurnal variation at these periods, the summer and winter means, as well as the annual means, were tabulated. The months from April to September (inclusive) comprise the summer period, and from October to March (inclusive) the winter period. The first diagram, (A,) on Sketch No. 7, shows this variation, and contains the type curves for these half-yearly periods. We find for the summer months a diurnal range of nearly 10½ minutes, and for the winter months of but 5½ minutes. These and other curves will be further analyzed hereafter.

The second diagram, (B,) Sketch, No. 7, exhibits the same phenomenon in a different way, the yearly curve of the first diagram being straightened out and forming the axis of the second diagram, which thus shows the deviations from the annual mean value for the two seasons, when the sun has north and south declination. The ordinates are obtained by subtracting the annual mean from either the summer or winter mean in the preceding table. This diagram further exhibits in quite a characteristic manner the course of the annual variation at the different hours of the day at the season for which the diagram is constructed. Thus at the hours six or seven in the morning the annual variation is a maximum, disappearing at a quarter before 10 a. m., and reaching a second (secondary) maximum value at 1 p. m. It almost disappears soon after 5 p. m., and a third still smaller maximum is reached after 9 p. m.; half an hour before midnight the annual variation again disappears. At (and before and after) the principal maximum between six and seven in the morning the annual variation causes the north end of the magnet to be deflected to the east in summer and to the west in winter, at 1 p. m. the deflections are to the west in summer and to the east in winter. The range of the diurnal motion is thus increased in summer and diminished in winter; the magnet being deflected in summer more to the east in the morning hours, and more to the west in the afternoon hours, or having greater elongations than it would have if the sun moved in the equator. In winter the converse is the case.

The range of the annual variation from summer to winter is about 3'.0, and its daily range about 2'.6 at Philadelphia. The next diagram (C) has been projected in order to illustrate the semi-annual inequality of the diurnal variation at four principal magnetic stations.* The general features of the Philadelphia curve most nearly resemble those exhibited by the St. Helena curve, and relatively the Toronto and Hobarton curves appear to represent rather extremes than normal shapes. The Philadelphia and St. Helena curves have another feature in common, the amplitude at its maximum value shortly after 6 a. m. is less than the amplitude at Toronto and Hobarton; and upon the whole the Philadelphia type confirms the idea that all forms partake of the same general character, more or less affected by incidental irregularities.

In reference to the annual variation, General Sabine, in the "rectifications and additions" to the last volume of Humboldt's Cosmos, expresses himself as follows: * * * "Thus in each hemisphere the semi-annual deflections concur with those of the mean annual variation for half the year, and consequently augment them, and oppose and diminish them in the other half. At the magnetic equator there is no mean diurnal variation, but in each half year the alternate phases of the sun's annual inequality constitutes a diurnal variation, of which the range in each day is about 3' or 4', taking place every day in the year except about the equinoxes, the march of this diurnal variation being from east in the forenoon to west in the afternoon, when the sun has north declination, and the reverse when south declination." * * *

According to the same authority the *annual* variation is the *same* in both hemispheres, the north end of the magnet being deflected to the east in the forenoon, the sun having north

* The annual variation of the diurnal motion has been made the subject of a particular discussion by General Sabine in papers presented to the British Association and to the Royal Society. See reports of the British Association, 1854, pp. 355-363, and Trans. Royal Society, May 18, 1854, pp. 67-82; also, art. xxviii, Philosophical Trans., 1851.

declination, when in the *diurnal* variation the north end of the magnet at that time of the day is deflected to the east in the northern hemisphere, and to the west in the southern hemisphere. In other words, in regard to direction, the law of the annual variation is the same, and that of the diurnal variation the opposite in passing from the northern to the southern magnetic hemisphere.

I next proceed to consider more in detail the annual variation at the hours of six and seven in the morning, and of one and two in the afternoon, these being the hours of the principal and secondary maximum, respectively. By subtracting the annual mean from each monthly value, at the respective hours, we obtain from the preceding general table the following columns:

Annual variation at the hours of the principal and secondary maximum of range.

$\left.\begin{matrix}+\\-\end{matrix}\right\}$ indicates $\left\{\begin{matrix}\text{west}\\\text{east}\end{matrix}\right\}$ deflection from the mean annual position.

Month.	6*h*. a. m.*	7*h*. a. m.*	Mean.	1*h*. p. m.†	2*h*. p. m.†	Mean.
	′	′	′	′	′	′
January	+2.15	+1.86	+2.01	−1.20	−0.76	−0.98
February	+1.38	+1.25	+1.31	−1.09	−1.15	−1.12
March	+0.75	+0.19	+0.47	−0.19	−0.75	−0.47
April	−0.52	+0.82	+0.15	+0.88	+1.25	+1.06
May	−1.32	−1.43	−1.38	+0.92	+0.94	+0.93
June	−2.03	−1.78	−1.90	+0.84	+0.93	+0.89
July	−1.72	−2.16	−1.94	+1.21	+1.30	+1.25
August	−2.31	−3.00	−2.66	+1.39	+1.23	+1.31
September	−1.14	−1.34	−1.24	+1.24	+0.40	+0.82
October	+1.52	+1.30	+1.41	−1.24	−1.05	−1.14
November	+1.28	+1.66	+1.47	−1.31	−1.40	−1.35
December	+1.99	+2.60	+2.30	−1.43	−0.96	−1.20

* Maximum range (at the above hours) 5′.0, the easterly deflection being greater by 0′.4 than the westerly.
† Range at the hours 1 and 2 p. m. 2′.7, the eastern and western deflection being equal.

A general inspection of the above columns containing the mean values shows that, approximately, the solstices are the turning epochs of this annual variation, the signs changing at the time of the equinoxes. To ascertain how nearly this is true, and in order to obtain a more precise expression, the means of the two columns, (after changing the signs in the second,) for each month, respectively, were put into an analytical form, using Bessel's well-known formula for periodic functions:

$$\triangle_a = +\ 1'.78 \text{ sin. } (\theta + 90^\circ) + 0'.32 \text{ sin. } (2\,\theta + 180^\circ;)$$

$$\text{or, } \triangle_a = +\ 1'.78 \text{ cos. } \theta - 0'.32 \text{ sin. } 2\,\theta,$$

the angle θ counting from January 1.

The maximum values will occur on the first of January and the first of July, and the transition from a positive to a negative value, and the reverse, will take place on the first of April and the first of October, the equation $1'.78 \text{ cos. } \theta = 0'.32 \text{ sin. } 2\,\theta$ being only satisfied for $\theta = 90^\circ$ and 270°. That the angles C_1 and C_2 should be exactly 90° and 180° is remarkable. The monthly values are satisfied as follows:

Month.	By observation	By calculation.
	′	′
Middle of January	+1.50	+1.56
February	+1.22	+0.94
March	+0.47	+0.30
April	—0.46	—0.30
May	—1.16	—0.94
June	—1.40	—1.56
July	—1.59	—1.56
August	—2.00	—0.94
September	—1.03	—0.30
October	+1.28	+0.30
November	+1.41	+0.94
December	+1.76	+1.56

The regular progression of the monthly values is a feature of the annual variation deserving particular notice. There is no sudden transition from the positive to the negative side, or, vice versa, at or near the time of the equinoxes, (certainly not at the vernal equinox;) on the contrary, the annual variation seems to be regular in its progressive changes. The method here pursued is entirely different from that employed by General Sabine for the same end; but the results are, nevertheless, in close accordance. He remarks, (in the British Association's report, above cited,) "when a mean is taken corresponding to the 10th or 11th day after the equinox the transition from the character of the preceding six months has already commenced and advanced very far towards its completion, and by the middle of October is quite complete; apparently the progress of the change is somewhat more tardy in the March than in the September equinox."

From the above analysis we have found that the transition took place *ten* days after either equinox, and, also, that the turning points occur ten days after the solstices.

For the more precise determination of the law of the phenomenon, and in order to render the results of similar investigations comparable with one another, the regular solar-diurnal variation is now to be expressed as a function of the time.

The preceding tabular values, given in minutes of arc, when treated as required by Bessel's* periodic function, furnish the following expressions for each month of the year:

For January···· $\Delta_d = + 1'.423 \text{ sin. } (15 n + 225° 09') + 1'.491 \text{ sin. } (30 n + 16° 38'.)$
$+ 0'.579 \text{ sin. } (45 n + 220° 23') + 0'.548 \text{ sin. } (60 n + 53° ......)$

For February ·· $\Delta_d = + 1'.469 \text{ sin. } (15 n + 211° 09') + 1'.456 \text{ sin. } (30 n + 20° 50'.)$
$+ 0'.472 \text{ sin. } (45 n + 231° 59') + 0'.352 \text{ sin. } (60 n + 60° .....)$

For March······ $\Delta_d = + 2'.098 \text{ sin. } (15 n + 206° 46') + 1'.827 \text{ sin. } (30 n + 26° 34'.)$
$+ 0'.693 \text{ sin. } (45 n + 230° 10') + 0'.413 \text{ sin. } (60 n + 84° .....)$

For April ······ $\Delta_d = + 2'.906 \text{ sin. } (15 n + 213° 21') + 2'.001 \text{ sin. } (30 n + 34° 01'.)$
$+ 0'.926 \text{ sin. } (45 n + 223° 29') + 0'.245 \text{ sin. } (60 n + 80° ......)$

For May ······· $\Delta_d = + 2'.746 \text{ sin. } (15 n + 210° 38') + 2'.377 \text{ sin. } (30 n + 45° 50'.)$
$+ 0'.970 \text{ sin. } (45 n + 251° 57') + 0'.100 \text{ sin. } (60 n + 161° .....)$

For June ······ $\Delta_d = + 2'.883 \text{ sin. } (15 n + 204° 09') + 2'.438 \text{ sin. } (30 n + 44° 15'.)$
$+ 0'.941 \text{ sin. } (45 n + 254° 03') + 0'.216 \text{ sin. } (60 n + 114° .....)$

* For another development of the formula see Rev. Dr. H. Lloyd's paper "on the Mean Results of Observations;" Transactions Royal Irish Academy, 1848, vol. xxii, Part 1: Dublin, 1849.

For July ······· $\Delta_d = +\ 3'.310 \text{ sin. } (15\ n + 204^\circ\ 19') + 2'.465 \text{ sin. } (30\ n + 38^\circ\ 48'.)$
$+\ 1'.047 \text{ sin. } (45\ n + 251^\circ\ 38') + 0'.092 \text{ sin. } (60\ n + 176^\circ.....)$

August ···· $\Delta_d = +\ 3'.161 \text{ sin. } (15\ n + 211^\circ\ 37') + 2'.849 \text{ sin. } (30\ n + 52^\circ\ 16'.)$
$+\ 1'.375 \text{ sin. } (45\ n + 265^\circ\ 49') + 0'.201 \text{ sin. } (60\ n + 51^\circ...)$

September.. $\Delta_d = +\ 2'.706 \text{ sin. } (15\ n + 220^\circ\ 05') + 2'.372 \text{ sin. } (30\ n + 55^\circ\ 54'.)$
$+\ 1'.126 \text{ sin. } (45\ n + 261^\circ\ 14') + 0'.414 \text{ sin. } (60\ n + 115^\circ...)$

October···· $\Delta_d = +\ 1'.271 \text{ sin. } (15\ n + 226^\circ\ 29') + 13'.25 \text{ sin. } (30\ n + 33^\circ\ 12'.)$
$+\ 0'.727 \text{ sin. } (45\ n + 230^\circ\ 52') + 0'.150 \text{ sin. } (60\ n + 47^\circ...)$

November·· $\Delta_d = +\ 1'.259 \text{ sin. } (15\ n + 229^\circ\ 06') + 1'.257 \text{ sin. } (30\ n + 39^\circ\ 15'.)$
$+\ 0'.390 \text{ sin. } (45\ n + 236^\circ\ 30') + 0'.242 \text{ sin. } (60\ n + 87^\circ....)$

December ·· $\Delta_d = +\ 1'.212 \text{ sin. } (15\ n + 231^\circ\ 46') + 1'.321 \text{ sin. } (30\ n + 23^\circ\ 34'.)$
$+\ 0'.367 \text{ sin. } (45\ n + 205^\circ\ 46') + 0.418 \text{ sin. } (60\ n + 32^\circ....)$

In like manner we obtain for the summer half year from April to September, inclusive, for the winter half year from October to March, inclusive, and for the whole year, the following expressions for the diurnal variation:

For summer half year $\Delta_d = +\ 2'.936 \text{ sin. } (15\ n + 210^\circ\ 36') + 2'.404 \text{ sin. } (30\ n + 46^\circ\ 7'.)$
$+\ 1'.031 \text{ sin. } (45\ n + 253^\circ\ 37') + 0'.178 \text{ sin. } (60\ n + 132^\circ\ 20'.)$

For winter half year $\Delta_d = +\ 1'.420 \text{ sin. } (15\ n + 220^\circ\ 41') + 1'.399 \text{ sin. } (30\ n + 26^\circ 39'.)$
$+\ 0'.520 \text{ sin. } (45\ n + 227^\circ\ 26') + 0'.310 \text{ sin. } (60\ n + 61^\circ\ 17'.)$

For whole year* ···· $\Delta_d = +\ 2'.167 \text{ sin. } (15\ n + 213^\circ\ 55') + 1'.875 \text{ sin. } (30\ n + 38^\circ\ 52'.)$
$+\ 0'.759 \text{ sin. } (45\ n + 244^\circ\ 40') + 0'.198 \text{ sin. } (60\ n + 83^\circ\ 05'.)$

In determining the least square coefficient in these equations allowance has been made for the different heights due to the readings at the odd and even hours; θ is reckoned from midnight at the rate of 15° an hour. To compare the numerical quantities of the angles $C_1\ C_2\ C_3\ C_4$ in the general expression $\Delta_d = B_1 \text{ sin. } (\theta + C_1) + B_2 \text{ sin. } (2\ \theta + C_2) + B_3 \text{ sin. } (3\ \theta + C_3) + B_4 \text{ sin. } (4\ \theta + C_4)$ with the same quantities in the formulæ of the diurnal variation, (pp. 8–9 of Part I,) 180° must first be added or subtracted from each angle given there, since in the discussion of part I *increasing* numbers correspond to a decrease of western declination, the scale being thus graduated, whereas in the *present* case *increasing* positive numbers correspond to an *increase* of western declination, as stated above.

* For the purpose of showing the correspondence when the above equation is deduced, *independently* from the observations at the even and odd hours, I add here the values for the two cases :

From even hours : $\Delta_d = +\ 2'.170 \text{ sin } (15n + 213^\circ\ 27') + 1'.888 \text{ sin } (30n + 38^\circ\ 59'.)$
$+\ 0.729 \text{ sin } (45n + 244^\circ\ 57') + 0.183 \text{ sin } (60n + 83^\circ\ 26')$

From odd hours : $\Delta_{d2} = +\ 2.159 \text{ sin } (15n + 215^\circ\ 19') + 1.835 \text{ sin } (30n + 38^\circ\ 31'.)$

If, for the purpose of comparison with the previous results in Part I of this discussion, and with other similar expressions, we change the angles $C_1\ C_2\ C_3\ C_4$, by 180°—which is equivalent to an easterly deviation from the mean for positive results and to a westerly deviation for negative results—we find :

For Philadelphia : $\Delta_d = +\ 2'.167 \text{ sin } (\theta + 33^\circ\ 55') + 1'.875 \text{ sin } (2\theta + 218^\circ\ 52'.)$
$+\ 0.759 \text{ sin } (3\theta + 64^\circ\ 40') + 0.198 \text{ sin } (4\theta + 263^\circ\ 05'.)$

For Dublin : $\Delta_d = +\ 3.519 \text{ sin } (\theta + 64^\circ\ 18') + 2.127 \text{ sin } (2\theta + 225^\circ\ 22'.)$
$+\ 0.688 \text{ sin } (3\theta + 70^\circ\ 40') + 0.322 \text{ sin } (4\theta + 242^\circ\ 27'.)$

This latter expression is copied from the Rev H. Lloyd's discussion of the Dublin observations in 1840 and 1843.

For a comparison of the monthly equations the reader may also consult similar expressions obtained by Karl Kreil from his discussion of declinometer observations at Prague, extending over ten consecutive years, (1840–1849) and selected from a thirteen years' series, in order to obtain mean results *unaffected* by the smaller inequality of the ten or eleven year period with which our results are still affected. Part I of the present discussion, however, affords ready means of changing slightly the numerical values of the coefficients $B_1\ B_2\ B_3\ B_4$ in our equations, in order to obtain the values we would have obtained had we discussed a consecutive eleven year series of observations, or one extending over a series of years corresponding to the actual length of the solar period then observed. Kreil's discussion will be found in Vol. VIII of the proceedings of the mathematical and physical section of the Imperial Academy of Sciences at Vienna, 1854.

The following table exhibits the close correspondence of the computed and observed mean annual value of the regular solar-diurnal variation :

Philada. mean time.	DIURNAL VAR.		C—0.	Philada. mean time.	DIURNAL VAR.		C—0.	Philada. mean time.	DIURNAL VAR.		C—0.
	Comp'd.	Observed.			Comp'd.	Observed			Comp'd.	Observed	
	′	′	′		′	′	′		′	′	′
0h. 19¼m	−0.49	−0.47	−0.02	8h. 19¼m	−3.44	−3.50	+0.06	16h. 19¼m	+1.71	+1.80	−0.09
1 19¼	−0.48	−0.51	+0.03	9 19¼	−1.29	−2 43	+0.14	17 19¼	+0.88	+0.78	+0.10
2 19¼	−0.51	−0.44	−0.07	10 19¼	−0.24	−0.19	−0.05	18 19¼	+0.33	+0.25	+0.08
3 19¼	−0.67	−0.71	+0.04	11 19¼	+2.03	+2.17	−0.14	19 19¼	−0.07	−0.07	0.00
4 19¼	−1.09	−1.19	+0.10	12 19¼	+3.69	+3.65	+0.04	20 19¼	−0.38	−0.33	−0.05
5 19¼	−1.82	−1.64	−0.18	13 19¼	+4.28	+4.32	−0.04	21 19¼	−0.57	−0.60	+0.03
6 19¼	−2.77	−2.72	−0.05	14 19¼	+3.81	+3.77	+0.04	22 19¼	−0.62	−0.64	+0.02
7 19¼	−3.49	−3.47	−0.02	15 19¼	+2.77	+2.76	+0.01	23 19¼	−0.57	−0.71	+0.14

The maximum difference of any one hour is less than 11″ and the probable error of any single hourly result is ± 0′.05. The probable error of any single computed value from a monthly expression is ± 0′.19.

By means of the preceding equations the hourly values of the diurnal variation for each month of the year have been computed and the results projected in curves are given in Diagrams D and E, Sketch No. 7. The first contains the curves for the six months of the summer half year and the second those of the winter half year. Positive ordinates correspond to a westerly movement and negative ordinates to an easterly movement of the north end of the magnet. Diagram F, Sketch No. 7, contains the type curves for summer, winter, and the whole year, all being upon the same scale.

Regular solar diurnal variation of the magnetic declination, computed for every month of the year and for the principal seasons.

Mean epoch, 1842–'43.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	′	′	′	′	′	′	′	′	′	′	′	′
January	−0.52	−0.24	−0.30	−0.48	−0.48	−0.38	−0.55	−1.24	−2.12	−2.45	−1.59	+0.26
February	−0.30	−0.09	−0.14	−0.32	−0.49	−0.71	−1.18	−1.90	−2.52	−2.49	−1.49	+0.24
March	−0.25	−0.32	−0.55	−0.71	−0.81	−1.09	−1.84	−2.93	−3.67	−3.40	−1.81	+0.55
April	−0 88	−1.14	−1.34	−1.44	−1.54	−1.88	−2.64	−3.55	−4.02	−3.42	−1.54	+1.11
May	−0.58	−0.59	−0.50	−0.59	−1.18	−2.32	−3.75	−4.74	−4.66	−3.24	−0.81	+1.93
June	−0.19	−0.28	−0.41	−0.69	−1.32	−2.45	−3.87	−5.02	−5.13	−3.80	−1.23	+1.69
July	−0.80	−0.82	−0.67	−0.72	−1.34	−2.62	−4.22	−5.42	−5.45	−4.04	−1.47	+1.47
August	−0.62	−0.33	−0.21	−0.59	−1.60	−3 09	−4.68	−5.71	−5.48	−3.67	−0.58	+2.87
September	−0.52	−0.72	−0.90	−1.06	−1.42	−2.23	−3.51	−4.55	−4.50	−2.84	+0.11	+3.18
October	−0.44	−0.53	−0.30	−0.20	−0.16	−0.45	−1.33	−1.72	−2.18	−1.92	−0.79	+0.77
November	−0.23	−0.21	−0.32	−0.44	−0.56	−0.75	−1.18	−1.68	−1.91	−1.50	−0.37	+1.11
December	−0.36	+0.01	−0.02	−0.34	−0.60	−0.67	−0.73	−1.00	−1.44	−1.64	−1.09	+0.26
Summer	−0.63	−0.71	−0.71	−0.81	−1.33	−2.43	−3.84	−4.92	−4.91	−3.43	−0.83	+2.12
Winter	−0.41	−0.26	−0.29	−0.42	−0.50	−0.68	−1.09	−1.73	−2.25	−2.15	−1.12	+0.56
Year	−0.49	−0.48	−0.55	−0.62	−0.94	−1.54	−2.41	−3.31	−3.54	−2.80	−1.02	+1.32

TABLE—Continued.

Mean epoch, 1842–'43.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	′	′	′	′	′	′	′	′	′	′	′	′
January	+2.26	+3.40	+3.34	+2.46	+1.52	+0.92	+0.57	+0.08	—0.64	—1.29	—1.45	—1.08
February	+1.96	+2.97	+3.02	+2.42	+1.71	+1.17	+0.76	+0.26	—0.36	—0.85	—0.97	—0.70
March	+2.71	+3.86	+3.85	+3.17	+2.33	+1.65	+1.02	+0.35	—0.31	—0 70	—0.67	—0.43
April	+3.60	+5.06	+5.18	+4.28	+2.98	+1.76	+0.88	+0.27	—0.14	—0.38	—0.54	—0.67
May	+4.06	+5.07	+4.88	+3.85	+2.48	+1.22	+0.39	—0.02	—0.12	—0.14	—0.21	—0.43
June	+3 99	+5.00	+4.79	+3.79	+2.60	+1.59	+0.87	+0.38	+0 07	—0.10	—0.13	—0.15
July	+3 90	+5.26	+5.37	+4.54	+3.28	+2.04	+1.16	+0.66	+0.39	+0 18	—0.15	—0.53
August	+5.44	+6.35	+5.55	+3.75	+1 98	+0.87	+0.50	+0.45	+0.26	—0.13	—0.56	—0.77
September	+5.18	+5.54	+4.48	+2.99	+1.68	+0.85	+0.33	—0.11	—0.44	—0.56	—0.55	—0.44
October	+2.60	+3.17	+3.00	+2.20	+1.08	+0.25	—0.39	—0.36	—0.39	—0.52	—0 69	—0.69
November	+2.31	+2.81	+2.58	+1.90	+1.18	+0.57	+0.06	—0.40	—0.59	—0.92	—0.77	—0.49
December	+1.86	+2.95	+3.04	+2.32	+1.34	+0.57	+0.11	—0.28	—0.78	—1.22	—1.33	—0.96
Summer	+4.35	+5.29	+4.99	+3.89	+2.57	+1.43	+0.64	+0.18	—0.05	—0.17	—0.33	—0.44
Winter	+2.21	+3.12	+3.09	+2.38	+1.52	+0.84	+0.37	—0.09	—0.55	—0.89	—0.94	—0.72
Year	+3.25	+4.22	+4.09	+3.14	+2.06	+1.12	+0.45	+0.05	—0.32	—0.52	—0.58	—0.58

In the above table + signifies westerly and — easterly deflection; it may be compared with similar tables constructed for Toronto*, Dublin†, and Prague‡. It will be observed that the preceding table, which gives the observed variation, refers to an epoch 19½ minutes later than the exact local hour, (that is, to an exact Gottingen hour,) whereas the computed table refers to the exact Philadelphia hours. From the computed tabular values, aided by the diagrams, we can now deduce some of the general features of the diurnal variation and its annual inequality.

The general character of the diurnal motion (see type curves) is nearly the same throughout the year; the most eastern deflection is reached a quarter before 8 o'clock in the morning, (about a quarter of an hour earlier in summer, and half an hour later in winter,) near this hour the declination is a minimum; the north end of the magnet then begins to move westward and reaches its westward elongation about a quarter after one o'clock in the afternoon, (a few minutes earlier in summer.) At this time the declination attains its maximum value. The diurnal curve presents but a single wave, slightly interrupted by a deviation occurring during the hours near midnight, (from about 10 p. m., to 1 a. m.,) when the magnet has a direct or westerly motion; shortly after 1 a. m. the magnet again assumes a retrograde motion and completes the cycle, by arriving at its eastern elongation shortly before 8 o'clock in the morning. This noctural deflection is well marked in winter, vanishes in the summer months, and is hardly perceptible in the annual curve; according to the investigations of Gen. Sabine, it is probable that if we had the means of entirely obliterating the effect of disturbances, this small oscillation would almost disappear. In summer, when it has no existence, the magnet remains nearly stationary between the hours of 8 p. m. and 3 a. m., a feature which is also shown by the annual type curve.

The two preceding plates show a close general resemblance in the diurnal curves for the six months, when the sun has north declination, and a similar resemblance in the other six months, when it has south declination. The analytical expression gives the epoch and amount of variation with greater precision. The hours of minimum and maximum deflection are obtained from the equation $\frac{d \triangle d}{dn} = 0$, and the hours of the mean declination when the curves cross the axis of abscissae from the condition $\triangle_d = 0$.

* Vol. III, Table LXVI, compare also with table VII of Vol. II.

† Transactions Royal Irish Academy, Vol. XXII, part I, Table III.

‡ Academy of Sciences at Vienna, Vol. VIII, of Math. Section, Table II.

The following table contains these results for each month and the two principal seasons of the year, also the critical interval between the two adjacent hours of the mean position:

Months.	East elongation.	West elongation.	Critical interval from minimum to maximum.	Epoch of mean declination.		Critical interval.
	A. M.	P. M.		A. M.	P. M.	
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
January	8 58	1 27	4 29	10 52	7 08	8 16
February	8 34	1 32	4 58	10 52	7 26	8 34
March	8 07	1 34	5 27	10 46	7 32	8 46
April	8 12	1 27	5 15	10 34	7 40	8 56
May	7 29	1 21	5 52	10 19	6 57	8 38
June	7 33	1 20	5 47	10 25	8 26	10 01
July	7 36	1 28	5 52	10 30	9 32	11 02
August	7 18	1 05	5 47	10 10	8 40	10 30
September	7 30	0 45	5 15	9 58	6 45	8 47
October	8 00	1 17	5 17	10 30	5 23	6 53
November	7 54	1 08	5 14	10 16	6 08	7 52
December	8 54	1 40	4 46	10 50	6 17	7 27
Summer	7 33	1 8	5 35	10 17	7 43	9 26
Winter	8 24	1 25	5 01	10 40	6 49	8 09
Year	7 48	1 16	5 28	10 26	7 08	8 42

We likewise obtain:

Secondary minimum of eastern deflection in winter	9h. 42m. p. m.	Amount	— 0′.97
Secondary maximum of western deflection in winter	1 15 a. m.	Amount	— 0′.26
Differences	3 33		0′.71

And—

Secondary minimum of eastern deflection for the year	10h. 11m. p. m.	Amount	— 0′.62
Secondary maximum of western deflection for the year	1 13 a. m.	Amount	— 0′.47
Differences	3 02		0′.15

The effect of the seasons on the critical hours is well marked in the above table. The eastern elongation occurs earliest between the summer solstice and the autumnal equinox, and latest about the winter solstice; the western elongation occurs earliest about the autumnal equinox, and latest about the winter solstice; and the same holds good for the morning epoch of the mean declination. The afternoon epoch, however, occurs earliest shortly after the autumnal equinox, and latest shortly after the summer solstice. The critical hours which vary least during the year are those of the western elongation and those of the morning mean declination. The extreme difference between the value for any month and the mean annual value is 31 minutes in the former and 28 minutes in the latter.

The graphical representation of three variables (Diagram G, Sketch No. 7) will serve to show at a glance the various features of the diurnal variation and its annual inequality.

The magnetic surface is formed by contour lines 0′.5 apart; the dotted curves are lines of mean position; the curves represented by dashes correspond to eastern and the full curves to western deflection from the normal position.

This diagram, as well as the computed tabular values from which it has been constructed, furnish the correction necessary to reduce any single observation taken at any hour of the day and month to its mean value. It also enables us, in a measure, to dispense with developing the annual variability of the coefficients B_1 B_2 B_3 B_4, and C_1 C_2 C_3, (or, rather, the

equivalents $a_1\ b_1\ a_2\ b_2\ a_3\ b_3$, from which they are derived,) in the general expression $A + B_1 \sin. (\theta + C_1) + \&c.$ In most cases either a tabular or graphical interpolation between the two adjacent monthly values will fully answer the purpose. The diagram also distinctly exhibits the diurnal minima and maxima; the former represented by a valley, the latter by a ridge in the magnetic surface.

The magnitude of the diurnal range is next to be considered.

The following table contains the amount of the deflection at the eastern and western elongations, and the diurnal amplitude of the declination for each month of the year, derived from the preceding equations:

Months.	Deflection at east elongation.	Deflection at west elongation.	Diurnal range.	Months.	Deflection at east elongation.	Deflection at west elongation.	Diurnal range.
	′	′	′		′	′	′
January	−2.46	+3.52	5.98	July	−5.58	+5.46	11.04
February	−2.64	+3.11	5.75	August	−5.79	+6.36	12 15
March	−3.73	+4.03	7.76	September	−4.71	+5.60	10.31
April	−4.02	+5.28	9.30	October	−2.18	+3.23	5.41
May	−4.89	+5.16	10.05	November	−1.92	+2.85	4.77
June	−5.26	+5.06	10.32	December	−1.65	+3.14	4 79

The diurnal range for the summer months is 10′.45; for the winter months, 5′.56; and for the whole year, 7′.89; all corresponding to an epoch removed about one year and a half from the epoch of a minimum of the eleven year solar period.

The numbers expressing the diurnal range exhibit three remarkable features, viz: the maximum value in the month of August; the sudden falling off in the months of September and October, (see the graphical representation, Sketch No. 7;) and the minimum value in November or December. Otherwise, the progression is regular; the curve is *single crested*—a feature equally true for the eastern as well as for the western deflection when viewed separately. This latter circumstance is of special importance, since it is probable that it is mostly by the interference of these two separate curves that the curve of the diurnal range appears at some stations to be a double crested one. The curves for Milan, Munich, Göttingen, Brussels, Greenwich, Dublin, &c., for instance, exhibit two maxima: one after the vernal equinox, and a second—generally the smaller one—about the summer solstice, with more or less regularity. The system to which Philadelphia belongs is exemplified by the annual curve of the diurnal range at Prague and at some of the Russian stations, especially at Nertschinsk, but principally at Toronto, for which last station the curve is shown in the diagram. Neither station appears to have a tendency to a secondary maximum about the month of April, leaving the maximum about a month and a half after the summer solstice—a well-marked North American feature.

Annual variation of the declination.—In connection with the preceding discussion, the annual inequality in the magnetic declination next claims attention. This subject presents greater difficulty, inherent in the observations, than the diurnal inequality; not so much on account of the length of the period as on account of the difficulty of keeping the instrument in precisely the same condition of adjustment throughout the year. In the first part of this discussion I have already had occasion to refer to the circumstance while investigating the annual effect of the secular change; and it was there shown that the Philadelphia observations share in this

respect the difficulties of those of other stations,* in consequence of which the results must be received with caution.

Returning to the last vertical column in the table, headed "Mean," we have there the monthly values of the declinometer readings, (in scale divisions,) and in their differences, when compared month for month, the joint effect of the secular change and of the annual inequality. To eliminate the effect of the secular change, we determine its annual amount as follows: Subtracting the mean annual reading 559.64, corresponding to July 1, from each monthly mean, and putting $x =$ monthly effect of the secular change, (considered as uniform,) each monthly mean reading furnishes an equation for the determination of x. Thus, for—

January, $4.56 = 5.5\,x$; February, $3.34 = 4.5\,x$; March, $5.22 = 3.5\,x$; April, $4.39 = 2.5\,x$, &c., which, when combined by application of the method of least squares, give $x = 1d.227$; hence the annual change, $14d.7$, or $6'.7$ of *increasing westerly* declination.† Deducting the effect of the secular change, and comparing the monthly remainders with their mean values, we obtain the annual inequality of the declination as follows:

Month.	Mean reading.	Reduct. for sec. change.	Reduced reading.	Annual inequality.	Month.	Mean reading.	Reduct. for sec. change.	Reduced reading.	Annual inequality.
	d.	d.	d.	d.		d.	d.	d.	d.
January	564.20	−6.75	557.45	+2.2	July	560.24	+0.61	560.85	−1.2
February	562.98	−5.52	557.46	+2.2	August	559.07	+1.84	560.91	−1.3
March	564.86	−4.29	560.57	−0.9	September	556.07	+3.07	559.14	+0.5
April	564.03	−3.07	560.96	−1.3	October	556.43	+4.29	560.72	−1.1
May	563.18	−1.84	561.34	−1.7	November	553.97	+5.52	559.49	+0.2
June	560.84	−0.61	560.23	−0.6	December	549.82	+6.75	556.57	+3.1

The sign $\left\{ \begin{matrix} - \\ + \end{matrix} \right\}$ in the annual inequality indicates an $\left\{ \begin{matrix} \textit{easterly} \\ \textit{westerly} \end{matrix} \right\}$ deflection.

According to these results, the magnet (north end) is deflected to the east of its mean annual position in summer, and to the west in winter. It is, however, desirable, to test the result by submitting the first and the second $2\frac{1}{2}$ years of observations, separately, to the same process of investigation. The first 31 months in the years 1840–'41, and '42 give a result almost identical with that just deduced; the remaining 27 months in the years 1843–'44, and '45, when discussed in the same manner, give a rather different result. Some improvement, however, can be made on the preceding investigation by omitting the December mean of 1844, which is obviously about 12 scale divisions too small. The observed value is $535d.2$, and the interpolated value $547d.0$. An examination of the first series shows a defect in the monthly means of 1841, between May and June, requiring a constant correction of + 8.0 scale divisions for the remaining months after May, as may be seen by the following table:

* It may be proper to give here in full Dr. Lloyd's instructive note on this subject in his discussion of the Dublin observations: "The determination of the annual variation is much more difficult than that of the diurnal, both on account of the much smaller frequency of the period and the difficulty of preserving the instrument in the same unchanged condition during the much longer time, or of determining and allowing for its changes when they do occur. Accordingly, although the annual period may be traced in the observations of Gilpin, and is decidedly displayed in those of Bowditch, it has evaded the researches of recent observers. There is but a faint indication of its existence in the Göttingen observations, which were made at the hours of 8 a. m. and 1 p. m; and Prof. Gauss and Dr. Goldschmidt find, in their analysis of these observations, no important fluctuation dependent on season. A similar negative result is deduced by Dr. Lamont from the Munich observations, which were made twelve times in the day."

† This value, (+ 6'.7,) as resulting from a different combination of observed and partly interpolated values, may not be preferable to that (+ 4'.5) deduced in part I of this discussion, but must necessarily be employed in the present investigation. The most reliable value + 5'.0 was deduced from independent observations, as already remarked, and lies between the two.

Year.	May.	June.	Diff. May—June.	
1841	578.5	571.2?	....	Computed value for June, 579.2.
1842	561.8	563.6	—1.8	
1843	566.2	565.0	+1.2	
1844	546.5	547.5	—1.0	
1845	529.7	531.0	—1.3	
Mean	....	....	—0.7	

The following values then remain for the discussion, and they should be considered as forming the basis from which the legitimate results are to be deduced. The numbers marked with an asterisk have been increased by 8*d*.0. Interpolated values are between brackets, and were obtained by comparing the means of the remaining months of the year with the corresponding means of every other year. By this process several values are obtained for each interpolated number; the resulting mean is given in the table. The high value of 1841, and the low value of 1844, for the month of May, in some measure compensate.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
1840	(586.9)	(585.9)	(586.3)	(586.4)	(584.1)	586.9	588.4	587.4	585.2	579.9	573.9	570.5	....
1841	576.3	574.3	577.0	578.1	578.5	*579.2	*576.7	*576.9	*571.1	*575.2	*564.4	*567.4	....
1842	564.1	563.3	562.0	561.9	561.8	563.6	565.2	563.8	566.7	562.7	563.5	561.6	....
1843	(566.5)	(565.6)	(565.9)	567.2	566.2	565.0	564.7	563.6	558.3	559.0	556.1	557.6	....
1844	558.0	558.0	557.6	555.2	546.5	547.5	547.5	546.2	542.2	545.3	547.2	(547.0)	....
1845	531.0	531.3	532.0	527.1	529.7	531.0	(529.9)	(529.0)	(527.0)	(526.2)	(522.7)	(522.1)	....
Mean	563.8	563.1	563.5	562.6	561.1	562.2	562.1	561.2	558.4	558.1	554.6	554.4	560.4
Cor. for sec. change	—4.4	—3.6	—2.8	—2.0	—1.2	—0.4	+0.4	+1.2	+2.0	+2.8	+3.6	+4.4	....
Cor. means	559.4	559.5	560.7	560.6	559.9	561.8	562.5	562.4	560.4	560.9	558.2	558.8	....
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
Annual.	+1.0	+0.9	—0.3	—0.2	+0.5	—1.4	—2.1	—2.0	—0.0	—0.5	+2 2	+1.6	....
Variation in arc	+0.5	+0.4	—0.1	—0.1	+0.2	—0.6	—1.0	—0 9	—0.0	—0.2	+0.9	+0.7	....

This last result accords, in general, with that before deduced, but is much to be preferred.

From June to October the north end of the magnet is, accordingly, to the eastward of the mean annual position, (after the elimination of the secular change,) and in the remaining months of the year it is to the westward of this position. From the vernal equinox until after the summer solstice the motion is to the westward or retrograde, in regard to the advance of the secular change (to the westward.) This is in conformity with the law as given by Dr. Lloyd in the Dublin discussion, where the motion of the magnet is to the westward at this period of the year, or the reverse of the Philadelphia deflection; but the secular change is likewise reversed, the west declination diminishing at Dublin at the same time or more accurately between 1840 and 1843.

For further comparison I give here the results deduced from seven years' observation at Toronto between the years 1845 and 1851, a previous working up of a three years' series (middle year, 1846) not being deemed sufficiently distinctive in its results. The secular change is here 2′.0 per annum increasing westerly declination, whereas it was 4′.4 per annum at Philadelphia in 1843. As in the above result, + indicates west; —, east deflection.

Annual variation at Toronto between 1845 *and* 1851.

January	+ 0′.1	July	— 0′.8
February	— 0′.5	August	— 0′.2
March	— 0′.2	September	+ 0′.7
April	0′.0	October	+ 1′.0
May	— 0′.1	November	+ 0′.3
June	— 0′.5	December	+ 0′.3

In regard to the amount of inequality, the two stations agree remarkably well, the range remaining slightly below 2′ of arc. It has been supposed that this range at the same station is increasing or diminishing as the secular change increases or diminishes.

It may further be remarked that the general mean resulting from the above discussion at Philadelphia, viz., 560.4, is identical with the value given in Part I of the discussion, there deduced by an entirely different combination. The annual effect of the secular change, + 4′.4, is likewise in very close conformity with the value given in Part I, as found by a very different process.

The monthly values of the annual variation may serve to give the corrections to observed declinations in any month of the year needed to refer the same to the mean declination of the year, and may also be used in the more refined discussion of the secular change; in both cases only when the greatest accuracy is required.

APPENDIX No. 24.

Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, *and* 1845. *Part III.—Investigation of the influence of the moon on the magnetic declination. By A. D. Bache, LL.D.*

The existence of a sensible lunar effect on the magnetic declination has already been established by the labors of Brown, Kreil, Sabine, and others. It is, nevertheless, important to add the weight of new numerical results to those already obtained.

In the discussions of the Philadelphia observations of magnetic declination already presented to the association, I have shown how the influence of magnetic disturbances of the eleven year period of the solar diurnal variation and its annual inequality of the secular change, and of the annual variation may be severally eliminated, leaving residuals from which the lunar influence is to be studied.

Each observation was marked with its corresponding lunar hour and the hourly normals used for comparison.

This method of treatment of the subject is that followed by General Sabine in his discussion of the results of the British observations.*

* In reference to methods and results in general on this subject, the following papers may be consulted: Observations on Magnetism and Meteorology, made at Makerstown in Scotland, in the Observatory of General Sir Thomas M. Brisbane, Bart., in 1845 and 1846, forming vol. xix, part I, of the Trans. Roy. Society of Edinburgh: By John Allen Brown; Edinburgh, 1849. Also vol. xix, part II, containing the general results, (1850.)

Einfluss des Mondes auf die magnetische Declination, by Carl Kreil. Vol. III of the proceedings of the Mathematical and Physical Section of the Imperial Academy of Sciences of Vienna, 1852; also vol. v. ibid, 1853.

Philosophical Trans. Roy. Society, art. xix, 1853, on the influence of the moon on the magnetic declination at Toronto, St. Helena, and Hobarton. By Col. E. Sabine.

Phil. Trans. Roy. Society, art. xxii, 1856, on the lunar diurnal magnetic variation at Toronto. By Major General E. Sabine, and Phil. Trans. Roy. Society, art. I, 1857, on the evidence of the existence of the decennial inequality in the solar diurnal magnetic variations, and its non-existence in the lunar diurnal variation of the declination at Hobarton. By Major General E. Sabine.

The details of the method will be better understood by an example.

The time of the moon's passage over the meridian of Philadelphia (upper transit) was obtained from the American Almanac, the small correction for the difference of longitude being neglected. The observation nearest to the local mean solar time of the moon's transit was marked with a zero, signifying 0*h.* of lunar time. The time of the inferior transit was next obtained, and the observation nearest to it in time was marked 12*h.* The greatest difference in interval between the moon's transit and the time of observation could in no instance exceed half an hour. In the bi-hourly series, the observation nearest the moon's transit, or to either hour angle, one hour before or one hour after the transit, was marked. The mean of a number of differences for the same hours will thus give a result corresponding nearly enough with the hour. The number of observations intermediate between those marked 0*h.* and 12*h.* were marked with the corresponding hour angle by interpolation, care being taken to note the nearest full hour against each observation in the bi-hourly series. The hourly series begins with October 1843. In the case of thirteen observations within twelve lunar hours, the one nearest midway between the two consecutive lunar hours was omitted.

In the month of March, 1842, which is selected as an example of the details of working the bi-hourly series, the number of observations available is 298, of which 148 correspond to western, and 150 to eastern hour angles. In the abstract which follows, + indicates a deviation of the north end of the magnet to the west, and — a deviation to the east of the respective normal position for the hour. The hourly normals are given in the first part of the discussion. No difference exceeds eight divisions, this being the limit in number indicated by the criterion.

Lunar diurnal variation from observations at Philadelphia, in March, 1842. *Differences from the hourly normals.*

WESTERN HOUR ANGLES.—MOON'S UPPER TRANSIT.

	0*h.*	1*h.*	2*h.*	3*h.*	4*h.*	5*h.*	6*h.*	7*h.*	8*h.*	9*h.*	10*h.*	11*h.*
	+ 4.1	+ 6.1	— 0.1	— 5.0	+ 1.3	— 0.9	— 0.1	+ 1.0	+ 2.5	+ 3.1	+ 0.9	— 4.1
	— 2.5	— 4.2	+ 2.0	+ 1.0	+ 7.2	+ 0.2	+ 7.8	0.0	+ 1.2	+ 2.0	+ 2.1	— 1.8
	+ 3.1	— 1.4	+ 4.6	+ 6.1	+ 1.4	+ 0.9	— 0.6	— 0.5	+ 4.2	— 2.7	+ 1.6	— 6.8
	— 4.3	+ 4.3	— 0.7	+ 1.8	+ 0.3	+ 1.2	+ 2.3	— 3.0	+ 1.0	+ 5.2	— 0.4	— 2.0
	— 1.9	— 0.5	+ 3.9	— 1.3	— 0.6	— 2.9	— 0.5	+ 1.4	+ 0.7	— 1.8	— 1.1	— 5.2
	+ 6.4	+ 1.0	+ 3.6	+ 1.9	— 4.8	+ 1.3	— 0.1	+ 2.1	— 3.3	+ 7.0	+ 1.7	+ 5.6
	+ 1.7	+ 3.3	+ 1.6	— 0.9	+ 3.1	— 2.3	— 1.6	— 6.2	+ 2.3	— 1.1	+ 6.5	+ 6.6
	— 0.7	+ 0.2	— 3.2	— 0.9	+ 2.9	— 3.8	— 3.8	— 3.1	— 4.5	— 5.5	— 1.9	— 1.8
	+ 0.8	— 5.1	+ 3.0	0.0		— 7.2	— 6.3	— 5.9	— 2.9	— 3.0	+ 2.6	+ 1.1
	+ 2.9	— 2.7	+ 3.1	+ 1.8		— 3.7	— 2.4	— 4.6	— 0.8	+ 4.4	— 1.7	+ 0.7
	— 1.7	+ 2.8		— 3.0		+ 0.5	+ 0.5	— 5.1	— 0.9	— 2.2	— 0.9	— 1.6
		— 1.3		— 1.9		+ 2.9	— 0.2	— 4.6		— 1.6	— 0.5	
		+ 2.2		— 1.4			— 5.9	— 4.2		— 1.9	— 2.9	
				+ 2.9			+ 3.5	— 1.6		— 1.9		
				+ 2.1				+ 2.0				
				+ 1.6								
Means....	*d.* + 0.72	+ 0.38	+ 1.78	+ 0.30	+ 1.35	— 1.15	— 0.53	— 2.15	— 0.05	— 0.29	+ 0.46	*d.* — 0.84

WESTERN HOUR ANGLES—Continued.—MOON'S LOWER TRANSIT.

	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	− 2.7	− 0.5	− 2.9	+ 0.5	+ 5.6	+ 0.5	+ 0.6	− 4.1	+ 1.6	− 4.9	+ 4.4	− 4.2
	− 0.2	− 2.4	− 1.9	− 0.4	− 3.4	− 1.7	− 2.8	+ 1.3	+ 6.5	− 5.4	− 0.3	+ 0.6
	− 1.7	+ 3.0	+ 2.9	− 0.6	− 2.0	− 0.6	− 1.6	+ 2.5	− 5.1	− 0.4	+ 6.9	− 3.1
	− 1.0	− 0.6	+ 0.5	− 7.2	− 1.4	− 3.2	− 1.0	− 0.6	− 0.6	+ 0.4	− 0.9	− 0.1
	+ 3.2	− 0 2	− 5.2	− 0 5	− 2.3	− 0.4	− 6.0	+ 0.3	+ 0.6	+ 0.7	+ 1.6	+ 1.2
	+ 0.9	+ 2.7	+ 3.4	− 1.1	+ 1.4	+ 2.2	− 3.3	− 4.2	+ 0.2	+ 0.1	− 1.1	+ 1.7
	+ 2.4	+ 2.6	+ 4.5	+ 3.4	+ 1.0	+ 1.4	− 3.8	− 3.3	− 0.7	− 0.4	− 2.8	+ 1.6
	+ 1.9	+ 4.9	+ 5.4	+ 4.7	− 1.0	+ 2.3	+ 2.9	− 0.3	− 3.6	− 2.2	− 1.5	− 3.5
	+ 7.4	− 0.7	− 1.1	+ 7.6	+ 5.8	− 0.1	− 0.7	− 2.0	+ 5.9	+ 1.5	+ 1.4	− 4.0
	+ 0.3	− 4.6	+ 6.4	+ 3.4	+ 3.0	− 0.5	− 3.0	+ 3.6	− 1.0	+ 1.2	+ 3.0	− 3.3
	+ 5.3	− 3.5	+ 1.6	− 0.1	− 0.3	− 3.0	+ 2.5	− 6.6	− 1.6	− 0.8	− 0.4	+ 0.6
	− 1.2	− 0.3	+ 1.5		− 1.1	− 1.0	− 0.7	− 3.7	+ 3.4	+ 5.6	− 3.4	+ 5.1
					+ 3.7		+ 4.9				− 6.5	+ 2.8
					− 1.5							
					+ 0.6							
					− 1.1							
Means....	d. + 1.22	+ 0.20	+ 1.25	+ 0.88	+ 0.44	− 0.34	− 0.92	− 1.43	+ 0.47	− 0.39	+ 0.03	d. − 0.35

Number of observations or differences at western hour angle	....	148
Do. do. eastern hour angle	....	150
Total	....	298

The following table contains the number of observations used in the discussion of the lunar diurnal variation :

Month.	1840.	1841.	1842.	1843.	1844.	1845.
January	....	168	265	....	577	591
February	....	263	257	....	571	535
March	....	293	298	....	551	575
April	....	283	278	276	522	561
May	....	276	285	309	596	603
June	300	276	280	300	566	542
July	272	292	267	290	593	....
August	269	262	254	244	541	....
September	253	250	247	283	522	....
October	223	214	221	571	517	....
November	271	230	289	590	517	....
December	237	268	316	595	549	....
Sum	1,825	3,075	3,257	3,458	6,622	3,407

Sum total, 21644.

If divided into western and eastern hour angles the annual numbers stand as follows :

Year.	Western hour.	Eastern hour.
1840	916	909
1841	1,523	1,552
1842	1,618	1,639
1843	1,724	1,734
1844	3,288	3,334
1845	1,700	1,707
Sum	10,769	10,875

The preceding results will be found inserted in their proper place in the following abstract of the mean monthly values for each observing month between 1840 and 1845.

Proceeding in this way the following results are obtained for the different months discussed:

MOON'S HOUR ANGLE.

1840.	U. T., 0*h*.	1*h*.	2*h*.	3*h*.	4*h*.	5*h*.	6*h*.	7*h*.	8*h*.	9*h*.	10*h*.	11*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
June*	−0.23	−0.25	−1.28	+0.95	−1.09	+0.11	−0.21	+0.30	−1.12	+1.60	−0.02	+0.55
July †	+0.52	+1.87	−0.56	+2.04	−1.98	+1.60	−1.34	+0.40	−0.21	+0.47	+0.11	+0.75
August	−0.71	−0.10	+1.41	+0.73	+1.05	+1.20	−0.50	−0.44	+0.10	+0.86	+0.20	+0.75
September ‡	+1.74	−0.52	+1.05	−0.87	−0.40	−2.05	−0.67	−1 18	+0.49	+0.28	+0.52	+1.53
October	+0.77	−1.13	+0.37	+0.98	+0.25	+1.23	−0.01	+0.71	−0.78	−0.63	−0.68	−3.61
November§	+1.11	+1.04	+1.21	+0.77	+1.07	+1.44	−0.39	−0.53	−1.44	−2.03	−0.08	−1.61
December	−1.43	+1.14	+0.37	+0.37	+0.16	−0.90	−0.73	−1.44	−1.03	+1.01	−0.81	+1.24

TABLE—Continued.

1840.	L. T., 12*h*.	13*h*.	14*h*.	15*h*.	16*h*.	17*h*.	18*h*.	19*h*.	20*h*.	21*h*.	22*h*.	23*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
June *	+0.50	+0.75	+0.38	+0.86	+0.19	+1.65	−0.72	+0.68	−1.35	+0.69	−2.30	+0.98
July †	+1.15	−1.08	−0.41	+0.32	−1.71	+1.03	+0.15	−0.18	−0.37	+1 00	−1.38	−0.03
August	+0.18	−1.56	−0.91	−0.65	−1.15	−0.03	+0.06	−2 61	+1.50	−1.30	−1.27	−0.50
September‡	+0.64	+0.38	+0.63	+2.25	+0.84	+1.26	−0.61	−0.01	−1.05	−0.61	−0.23	+0.20
October	+0.53	−0.59	+0.30	+1.18	−1.19	+0.63	−0.31	−0.99	−0.40	−0.40	+1.51	+1.05
November §	+0.75	−0.62	+0.02	−0.82	−0.49	+0.01	−0.02	+1.09	+0.88	+0.57	+0.14	+0.18
December	+0.91	−0.78	−0.67	−1.82	−0.06	−0.70	−2.57	+1.21	+0.63	+0.86	+0.64	+1.48

* The tabular values for this month are expressed in parts of the new or observatory scale, the quantities having been converted from parts of the old or college scale into parts of the new scale.

† The tabular numbers refer to the new scale, the values for the first eighteen days of the month having been converted as above.

‡ Attention was paid to the half-monthly normals for the hour 8*h*. 19½*m*., (mean observatory time.)

§ The index correction on and after the twenty-third day of the month was applied before the differences were taken.

MOON'S HOUR ANGLE.

1841.	☾'s U. T., 0*h*.	1*h*.	2*h*.	3*h*.	4*h*.	5*h*.	6*h*.	7*h*.	8*h*.	9*h*.	10*h*.	11*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
January	+0.86	−1.07	+0.54	+1.39	+0.50	−2.01	+0.89	−0.11	−1.52	+0.48	−0.12	−1.10
February	+1.48	−2.17	+1.12	+0.49	+0.49	+0.10	−0.10	−0.57	−0.38	+0.32	+0.92	+1.40
March	+1.67	+0.82	+0.64	+1.00	+0.61	+0.40	−0.39	−1.07	−1.21	+0.69	−0.65	−0.91
April	+1.57	+1.01	+0.45	+0.97	+0.20	+0.12	+0.39	+1.40	−0.27	−1.52	+0.48	−1.43
May	+0.19	+2.11	+0.69	+1.94	−0.05	+0.92	−0.39	−0.60	−0.73	−0.20	−0.94	+1.21
June	−0.56	+1.77	+0.07	+0.45	+2.18	+1.25	−1.15	−0.59	−2.40	−1.13	−0.42	−1.24
July	+0.84	+1.86	+0.46	−1.06	−0.62	−1.52	−0.80	−0.55	−0.88	−1.71	−0.24	+1.03
August	+1.95	+1.31	+1.73	+1.42	−1.17	−1.46	−1.48	−1.39	−2.06	−2.24	−1.72	+0.60
September	+1.05	+0.10	−0.45	−0.17	−3.50	−0.54	−0.55	−0 83	−1 47	+0.86	+1.29	+0.03
October*	−1.15	+0.26	−0.77	−0.06	−1.31	−0.82	−0.66	−0.61	−1.73	+1.73	+0.22	+1.09
November	+0.01	−0.08	+0.02	+0 54	+0.23	−1.08	+1.54	+0 52	+1.39	+0.02	−0.24	−0.06
December	−0.41	+0.10	+0.45	−0.71	−0.94	+0.55	−0.51	+1.09	+0.62	−0.47	+0.48	+0.08

* At 14*h*. 19½*m*., (observatory time,) the difference from the half-monthly normals was used.

TABLE—Continued.

1841.	L. T., 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	+1.33	+0.57	−0.04	−0.51	−0.50	+0.21	+0.25	−2.10	−0.21	−1.32	−0.07	0.00
February	−0.03	−1.30	−0.78	−0.30	−1.23	−2.01	−1.12	−1.08	+0.60	+1.30	+0.56	+1.07
March	+0.15	+0.18	+1.05	+0.23	−0.15	−0.59	−0.23	−0.93	−0.47	−0.98	+1.89	+0.35
April	+1.35	−1.05	−0.09	+0.90	−0.02	−1.13	−0.32	−1.67	−0.89	−0.13	−0.63	+0.02
May	+0.42	+1.44	+0.56	+0.24	−1.21	−0.89	−2.64	−0.85	−2 20	−1.09	+0.96	+0.90
June	+0.11	−1.42	−0 13	+0.67	+1.18	−0.55	+0.62	−1.14	+1.79	+0.01	−0.22	+0.80
July	+1.26	+1.50	+1.09	+1.76	+0 32	+0.45	−0.80	+0.01	−0.95	+0.27	−0.87	+0.44
August	+2.28	+0.51	+1.97	+1.19	+0.62	−1.81	−0.50	−1.07	−0.59	+1.66	+0.06	+1.20
September	+0.37	+0.41	+1.21	+0.95	−1.66	−0.44	−0.25	−0.45	+0.45	+0.19	+0.85	+0.44
October*	−1.73	+1.04	+0.76	+0.34	+0.18	+1.60	+0.97	+3.14	+1.30	+3.10	−0 61	−1.54
November	+1.01	+0.03	−1.20	−0.30	−1.89	−1.33	−0.72	−0.49	+0.50	−1.89	+0.79	−0.27
December	+0.73	−0.59	+0.80	−0.49	+0.71	−0.92	−0.67	−1.27	+0.12	+1.21	+1.76	+0.83

* At 14h. 19⅛m., (observatory time,) the difference from the half-monthly normals was used.

MOON'S HOUR ANGLE.

1842.	U. T., 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	−0.30	+0.64	−0.53	+0.02	+0.66	−0.61	+0.14	−1.48	+0.44	−1.20	+0.26	−1.84
February	−0.73	+0 88	+0.36	−0.13	−0.83	+0 67	+0.18	−1.80	−0.92	−0.73	−0.27	+0.04
March	+0.72	+0 38	+1.78	+0.30	+1.35	−1.15	−0.53	−2.15	−0.05	−0.29	+0.46	−0.84
April	−0.77	+0.92	+0.53	+0.37	−0.07	−0.39	−0.20	−1.65	+0.27	−0.42	+1.21	+0.10
May	−0.57	+1.78	+0.01	−0.16	+0.18	−1 01	−1.41	−0.97	−0 92	+0.08	−0.43	+0.42
June	+0.38	+0.69	−0.95	+1.64	−0.18	+0.77	−0.25	−0.32	+0.76	+1.18	+0.38	−0.74
July	+0.78	+0.16	+0.69	−0.07	+0.60	−0.76	−2.08	+0.08	−1.65	+0.87	−1.04	+3.03
August	+0.88	+0.82	−0.08	−1.03	+1.17	−0.91	−0.95	+0.67	+0.72	−1.24	−0.17	+1.65
September	+0.71	−0.52	−0.13	−0.95	+0.67	+0.96	−0.82	+0.34	+0.82	+0.35	+0.62	+1.36
October	+3.46	+0.38	+0.77	−0.29	+0.06	+0.02	−0.25	−2.21	−0.98	−1.39	+0.52	−1.09
November	−0 05	+0.38	−1.07	−0.46	−0.36	−1 10	−0.53	+0.43	−0.95	+0.54	+0.14	+0.29
December	−0.59	−0.36	−0.34	−1.15	−0.75	+0.26	−0.57	+0.24	+0.39	+0.64	+0.87	+0.16

TABLE—Continued.

1842.	L. T., 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	−0.18	−1.19	−0.11	−2.13	+0.17	−0.61	+0.45	+1.05	+0.72	+0.66	−0.12	+0.62
February	−0.91	+0.71	+0.52	+0.40	−0.97	−0.86	−1.11	+0.44	−0.12	+0 14	+0.08	+0.84
March	+1.22	+0.20	+1.25	+0.88	+0.44	−0.34	−0.92	−1.43	+0.47	−0.39	+0.03	−0.35
April	+3.28	−0 86	+0.13	−0.12	−1.05	−1.34	−1.36	+0.15	−1.22	+0.19	−0.94	+1.11
May	+1.13	+1.78	+1.59	+1.10	−0.59	−0 52	−0.68	−1.47	−1.05	+0.15	−0.70	+1.01
June	+0.20	−0.82	+1.45	+0.33	+1.73	−1.19	+0.05	−1.36	−1.04	−1.43	−1.35	−1.37
July	−0.32	+1.84	−0.86	−0.72	+0.59	−0.95	−0.27	+0.03	−1.22	+0.09	−0.58	+0.68
August	−0.68	+2 50	−1.34	+0.59	−1.41	−0.67	−0.79	−0.58	−0.96	−0.26	+1.68	+0.81
September	+0.46	+1.11	−1.94	+0.25	+0.99	−0.45	−1.64	+0 10	−1.70	+2.14	+1.50	+0.96
October	+1.31	+1.68	−0.62	+0.74	−1.87	−0.14	+1.08	+0.43	−0.16	−0.25	+0.71	−0.56
November	+0.47	+0.40	+0.91	−1.13	+0 02	+0.11	−0 22	−1.46	+0.05	+0.68	+0.94	+1.58
December	+0.53	+0.35	+0.12	−0.45	−1.12	+0.15	+0.35	+0.54	+0.40	+0.57	+0.21	+0.07

MOON'S HOUR ANGLE.

1843.*	U. T., 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
April	+0.87	+1.47	+1.66	+0.39	−0.42	−1 30	−2.64	−1.72	−1.99	−0 12	−1.63	−0.48
May	+0.94	+0 89	+1 54	+0.45	+0.27	+0.38	+0.23	−1.02	−0.79	−1.01	+0.47	+1.08
June	−0.13	−1.58	+0.18	−0.81	+0.67	+1.21	−0.31	+0.83	+0.16	+0.61	−0.10	+1.30
July	+2.10	+0.91	−0.71	+0 65	+0.69	+0.54	−0.62	+0.56	−0.39	−2.29	+1.05	−0.16
August†	−1.56	−0.81	−2.28	+1.17	−0 05	−1.12	+0.32	−1.24	+0.26	−0.22	−0.69	+0.46
September	−0.71	+0.26	−0.58	−0.85	−1.08	−0.23	−0.30	+1.74	−0.74	+0.37	−0.42	+0.58
October‡	+1.05	+0.14	+0.28	+0.17	−0.03	−0.93	+0.19	−0.52	−1.16	+0.27	+0.33	+0.33
November	+0.52	+0.16	−0.72	−0.47	−0.80	−0.84	−0.57	−0.72	−0 02	+0.23	−0.17	+0.72
December	−0.41	−0.24	−0.64	−1.15	−0 88	−0.41	+0.07	+0.08	+0.39	+0.99	+1.09	+1.28

TABLE—Continued.

1843.*	L. T., 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
April	+0.79	+1.92	+0.72	−0.06	+0.53	+0.05	−1.10	−1.05	−0.22	−1.06	−0.56	+1.58
May	+0.67	+0.74	+1.01	−0.58	−1.01	−1.03	−1.43	−0.27	−0.52	−0.49	+0 70	+0.08
June	+0.94	+1.46	−0.55	+0.29	−0.99	−0.05	−0.63	+0.07	−0.38	−0.22	+0.74	−0.20
July	−0.25	+0.61	+0.66	+0.66	−0.43	−1.10	−2 00	−1.05	−0.20	−0.06	−0.54	+1.73
August†	+0.91	−0.59	−0.77	+0.59	−1.85	+0.01	−1.00	+1.37	−0.92	+0 74	+0.49	+0.06
September	+1.63	+1.85	+0.78	+2.32	+1.15	−0.29	−0.86	+1.08	+0.65	−0.37	−0.90	−0.78
October‡	+0.76	+1.50	+1 30	+0.53	−0.71	−0.92	−1.76	−0.70	−0.08	+0.50	−0.37	+0.78
November	+0.67	+0.45	−0.33	−0.25	−0.54	+0.04	−0.24	+0.17	+1.06	+1.00	+0.27	+0.50
December	+0.83	+0.51	+0.60	+0.62	+0.28	−1.14	−0.59	−0.74	−0.46	+0.46	+0.24	−0.42

* There are no observations in January, February, and March of this year.
† Attention was paid to the shifting of the zero of the scale between the 9th and 10th.
‡ Commencement of the hourly series of observations.

MOON'S HOUR ANGLE.

1844.	U. T., 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January*	−0.79	−0.18	−0.26	+0.07	+0.20	+0.94	+0.58	+0.19	+0.22	+0.37	−0.46	+0.43
February	+1.43	+0.87	+0.67	−0.52	−0.69	−0.82	−0.56	−0.74	−0.29	+0.77	+1.03	+0.96
March	+1.10	+1.06	+0.42	+0.04	−0.72	−0.55	−0.69	−0.16	+1.18	+0.05	+0.93	−0.02
April	−0.52	+0.08	+0 23	+0.54	+0.09	+0 35	−0.49	−0.12	−0.55	−0.41	+0.16	−0.04
May	+0.76	+1.17	+0.88	+0.27	+0 02	−0.49	−0.18	−0.60	−0.35	−0.10	+0.14	+0.27
June	+1.11	+0.68	+1.07	+0.44	+0.09	−0.64	−0.24	−1.33	−1.58	−1.47	−0.40	+0.22
July	+1.09	+1.27	+0.78	+0.97	+0.18	−0.73	−1.05	−1.77	−0.17	−0.13	+0.68	+0.37
August	+2.30	+0.93	+0.19	−0.14	−0.16	−1.55	−0.78	−0.69	−0.38	−0.66	+0.45	+0.45
September	+1.13	+1.47	−0.21	−0.05	−0.61	−1.15	−0.31	+1 05	+1.10	−0 18	+0.12	−0.34
October	−0.22	+0.42	−0.02	+0.22	−0 41	−0.59	−0.78	+0.38	−0.02	+1.04	+1.10	+1.01
November	−0.91	−1.12	−0.71	−0.57	−0.76	+0.03	−0.01	+0.45	−0.77	+0.06	+0.62	+2.57
December†	−0.26	−0.74	−0.21	−0.44	−1.14	−0.33	−0.41	−0.18	+0.14	+0 33	+0.36	+0.60

* Proper attention was paid to the change in the zero of divisions after the 10th.
† The half-monthly normals were used.

TABLE—Continued.

1844.	L. T., 12*h*.	13*h*.	14*h*.	15*h*.	16*h*.	17*h*.	18*h*.	19*h*.	20*h*.	21*h*.	22*h*.	23*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
January*	+0.32	+0.10	+0.31	−0.09	−0.61	−0.17	+0.84	+0.95	+0.32	−0.10	−0.80	−0.48
February	+0.44	0.00	+0.54	−0.26	−1.10	−0.49	−1.13	−0.39	−0.02	−0.05	−0 02	+0.84
March	+1.33	+0.52	−0.50	−0.21	−0.21	−0.68	−1 60	−0.50	−0.31	−0.48	+0.35	−0.10
April	+0.87	+0 70	+0.37	+0.64	−0.22	−0.54	−0.50	+0.05	−0.66	−0.42	−0.02	−1.63
May	+0.46	+0.09	+0.74	+0.43	+0.62	+0.06	−0.19	−1.10	−0.85	−1.17	+0.10	+0.06
June	+0.19	+0.48	−0.30	−0.36	−0.01	+0.35	+0.31	+0.29	+0.25	+0.20	+0.11	0.00
July	+1.27	+0.36	+0.46	−0.70	−0.51	−0.70	−1.03	−0.13	−0.31	−0.57	−0.12	+0.78
August	+0.50	+0.22	+0.84	−0.30	−0.19	−0.77	−1.06	−0.75	−0.34	−0.14	−0.43	+0.76
September	+0.25	+0.04	+0.73	−0.20	−0.03	−1.20	−1.89	−1.27	−1.33	−0.62	+0.13	+1.15
October	+0.56	+1.19	+0.78	−0.10	−0.36	−0.32	−0.03	−0.83	−0.58	−0.55	+0 06	+0.06
November	+0.36	+1.09	+0.67	+0.43	+0.05	+0.40	+0.07	−0.77	−0 68	+0.41	+0.15	−0.11
December†	+0.48	+0.64	+1.06	−0.12	−0.12	−0.64	−0.22	+0.23	+0.26	+0.68	+0.17	+0.42

MOON'S HOUR ANGLE.

1845.	☾'s U. T., 0*h*.	1*h*.	2*h*.	3*h*.	4*h*.	5*h*.	6*h*.	7*h*.	8*h*.	9*h*.	10*h*.	11*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
January	−0.46	−1.65	−1.52	−1.65	−1 63	−0.24	+0.11	+1.41	+0.96	+1.83	+0.91	+1.11
February	−0.13	+0.48	−0.26	−1.15	−0.56	−0.81	−0.39	−0.28	+0.18	+1.03	+0.98	+1.28
March	−0.42	−0.47	−0.26	−0.48	−0.25	−0.75	−0.81	−0.25	+0.20	+0.39	+0.79	+0.91
April	+0.45	+0.54	+0.07	+0.52	−0.21	−0.47	−0.27	−0.07	−0.25	−0.03	+0.27	+1.08
May	+0.53	+0.49	+0.01	+0.16	−0.21	−0.22	−0.66	−0.25	−0.88	+0.04	+0.92	+0.43
June	+1.77	+1.63	+0.90	+1.24	+0.86	+0.54	−0.66	−1.09	−0.75	−0.93	−0.83	−0.31

TABLE—Continued.

1845.	☾'s L. T., 12*h*.	13*h*.	14*h*.	15*h*.	16*h*.	17*h*.	18*h*.	19*h*.	20*h*.	21*h*.	22*h*.	23*h*.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
January	+0.02	−0.26	−1.07	−0.60	−0.30	+0.14	+1.09	+0.29	+0.86	+0.34	+0.39	+0.38
February	+1.70	+0.67	−0.13	+0.40	+0.03	−0.76	−0.92	−1.26	−0.46	+0.17	−0.05	−0.09
March	+1.15	+0.95	+1.79	+0.35	+0.86	−0.08	−0.83	−1.27	−0.56	+0.37	−0.39	−0.73
April	+0.54	+0.56	0.00	+0.76	+1.01	−0.30	−1.00	−1.67	−1.62	−0.97	+0 37	−0.78
May	+0.53	+0 03	−0.63	−0.01	−0.24	−0.48	−0.70	−0.30	−0.40	−0 53	+1.16	+0.63
June	+0.01	+0.86	+0.30	+0.18	−0.33	−1.27	−0.82	−0.59	−0.92	+0.05	+0.74	+0.64

Value of a scale division, 0′.453.

One of the first questions to determine is, how many of these residuals must be used to give a definite result; and another one is, whether numbers deduced from different parts of the series would give harmonious results. To test both of these the observations were formed into three groups: one containing 4,900 in 19 months of 1840–'41; another 6,715 results in 21 months of 1842–'43, and a third 10,029 results in 18 months of 1844–'45: in all 21,644 results.

The following table contains the result for each group. Group II includes three months of the hourly series of observations treated as if only equal in weight to the bi-hourly series.

The sign Σ indicates the algebraic sum of the values in the preceding tables for the months comprised in each group, and for every hour angle of the moon. The lines headed I, II, III, contain the preceding values divided by their respective number of months and expressed in minutes of arc, or the lunar-diurnal variation.

* Proper attention was paid to the change in the zero of divisions after the 10th.
† The half-monthly normals were used.

MOON'S HOUR ANGLE.

	U. T., 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
Σ of group I	+10.27	+8.07	+7.52	+11.17	−4.32	−1.46	− 7.06	− 5.49	−14.63	−1.61	−1.70	+ 0.30
Σ of group II	+ 6.59	+7.35	−0.23	− 2.38	+0.87	−5.95	−10.90	−10.83	− 6.35	−2.78	+2.48	+ 7.65
Σ of group III	+ 7.96	+6.93	+1.77	− 0 53	−5.91	−7.48	− 7.60	− 4.05	− 2.01	+2.00	+7.77	+10.98
	′	′	′	′	′	′	′	′	′	′	′	′
I	+ 0.24	+0.19	+0.18	− 0.27	−0.10	−0.04	− 0.17	− 0.13	− 0.35	−0.04	−0.04	+ 0.01
II	+ 0.14	+0.16	0.00	− 0.05	+0.02	−0.13	− 0.24	− 0.23	− 0.14	−0.06	+0.05	+ 0.16
III	+ 0.20	+0.17	+0.05	− 0.02	−0.15	−0.19	− 0.20	− 0.10	− 0.05	+0.05	+0.20	+ 0.28

TABLE—Continued.

	L. T., 12h	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
Σ of group I	+11.91	− 2.18	+4.54	+6.00	−7.22	− 3.54	− 9.43	−8.71	−0.71	+3.14	+1.58	+7.60
Σ of group II	+13.46	+16.15	+4.52	+3.86	−6.64	−11.24	−14.67	−4.68	−6.90	+2.79	+1.53	+8.73
Σ of group III	+10.98	+ 8.22	+5.96	+0.24	−1.66	− 7.45	− 9.61	−9.02	−7.35	−3.38	+1.90	+1.80
	′	′	′	′	′	′	′	′	′	′	′	′
I	+ 0.29	− 0.05	+0.11	+0.14	−0.17	− 0.09	− 0.23	−0.21	−0.04	+0.08	+0.04	+0.18
II	+ 0.29	+ 0.35	+0.10	+0.08	−0.14	− 0.24	− 0.32	−0.10	−0.14	+0.06	+0.03	+0.19
III	+ 0.28	+ 0.21	+0.15	0.00	−0.04	− 0.19	− 0.24	−0.23	−0.19	−0.08	+0.05	+0.05

These results I, II, III, when expressed analytically by means of Bessel's form of periodic functions, and when treated by the method of least squares, are represented by the following equations, in which the moon's hour angle θ is reckoned from the upper transit westward at the rate of 15° to each hour. $\Delta_{☾}$ represents the lunar diurnal variation.

Group I, 1840–'41, $\Delta_{☾} = +\ 0'.003 + 0'.063 \sin. (\theta + 92°) + 0'.189 \sin. (2\theta + 67°)$

Group II, 1842–'43, $\Delta_{☾} = -\ 0'.006 + 0'.030 \sin. (\theta + 263°) + 0'.282 \sin. (2\theta + 63°)$

Group III, 1844–'45, $\Delta_{☾} = 0'.000 + 0'.075 \sin. (\theta + 292°) + 0'.219 \sin. (2\theta + 88°)$

+ indicates west, — east deflection from the normal position.

The numerical results from these equations are presented graphically on Sketch No. 7.

The curves all agree in their distinctive characters, and show two east and two west deflections in a lunar day; the maxima W and E occurring about the upper and lower culminations, and the minima at the intermediate six hours. The total range hardly reaches 0'.5. These results agree generally with those obtained for Toronto and Prague.

From 8,000 to 10,000 observations seem to be required to bring out the results satisfactorily, and the best results are derived from the use of all the groups.

The following table contains annual sums of deflection for each hour, and the resulting lunar-diurnal variation from the 21,644 observations available for the purpose:

WESTERLY HOUR ANGLES.

Year.	U. C., 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h	9h.	10h.	11h.
Σ for 1840	+1.77	+2.05	+2.57	+4.97	−0.94	+2.63	−3.85	−2.18	− 3.99	+1.56	−0.76	−0.40
Σ for 1841	+8.50	+6.02	+4.95	+6.20	−3.38	−4.09	−3.21	−3.31	−10.64	−3.17	−0.94	+0.70
Σ for 1842	+3.92	+6.15	+1.04	−1.93	+2.50	−3.25	−7.27	−8.82	− 2.07	−1.61	+2.55	+2.54
Σ for 1843(a)	+1.51	+1.14	−0.19	+1.00	+0.08	−0.52	−3.32	−0.85	− 3.49	−2.66	−1.32	+2.78
Σ for 1843	+1.16	+0.06	−1.08	−1.45	−1.71	−2.18	−0.31	−1.16	− 0.79	+1.49	+1.25	+2.33
Σ for 1844	+6 22	+5.91	+2.83	+0.83	−3.91	−5 53	−4.92	−3.52	− 1.47	−0.33	+4 73	+6 48
Σ for 1845	+1.74	+1.02	−1.06	−1.33	−2.00	−1.95	−2.68	−0.53	− 0.54	+2.33	+3.04	+4.50
Mean $\frac{\Sigma}{79}$	$+0^d.43$	$+0^d.37$	$+0^d.12$	$+0^d.08$	$-0^d.21$	$-0^d.31$	$-0^d.42$	$-0^d.32$	$-0^d.33$	$+0^d.01$	$+0^d.23$	$+0^d.41$
Same in arc	+0 .19	+0′ .17	+0′ .05	+0′ .04	−0′ .10	−0′ .14	−0′ .19	−0′ .14	−0′ .15	+0′ .01	+0′ .10	+0′ .19

HOUR ANGLES—Continued.

Year.	L. C., 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h	22h.	23h.	Months.
Σ for 1840	+4.66	−3.50	−0.66	+1.32	−3.57	+3.85	−4.02	−0.81	−0.16	+0.81	−2.89	+3.36	7
Σ for 1841	+7.25	+1.32	+5.20	+4.68	−3.65	−7.39	−5.41	−7.90	−0 55	+2.33	+4.47	+4.24	12
Σ for 1842	+6.51	+7.70	+1.10	−0.26	−3.07	−6.81	−5.06	−3.56	−5.83	+2.29	+1.46	+5.40	12
Σ for 1843(a)	+4.69	+5.99	+1.85	+3.22	−2.60	−2.41	−7.02	+0.15	−1.59	−1.46	−0.07	+2.47	6
Σ for 1843(b)	+2.26	+2.46	+1.57	+0.90	−0.97	−2.02	−2.59	−1.27	+0.52	+1.96	+0.14	+0.86	3
Σ for 1844	+7.03	+5.43	+5.70	−0.84	−2.69	−4.70	−6.43	−4.22	−4.25	−2.81	−0.32	+1.75	12
Σ for 1845	+3.95	+2.79	+0.26	+1.08	+1 03	−2 75	−3.18	−4.80	−3.10	−0 57	+2.22	+0.05	6
Mean $\frac{\Sigma}{79}$	$+0^d.63$	$+0^d.42$	$+0^d.29$	$+0^d.14$	$-0^d.23$	$-0^d.40$	$-0^d.58$	$-0^d.42$	$-0^d.27$	$+0^d.01$	$+0^d.09$	$+0^d.26$	37
Same in arc	+0′ .29	+0′ .19	+0′ .13	+0′ .06	−0′ .10	−0′ .18	−0′ .26	−0′ .19	−0′ .12	+0′ .01	+0′ .04	+0′ .12	21
													21
													79

The two values for 1843, marked *a* and *b*, exhibit the separate sums for the bi-hourly and the hourly observations, and were required to give proper weight to each. There are thirty-seven months of bi-hourly and twenty-one months of hourly observations, the latter having double weight, as found from a consideration of the probable errors derived, respectively, from all the results of the years 1842 and 1844. The probable error of any single monthly mean for any hour in the year 1842 was found $= \pm 0^d.60$, and the same for the year 1844 was $= \pm 0^d.40$. Hence the weights for a resulting value in the bi-hourly series is to the weight for a value in the hourly series nearly as 1 : 2, or nearly proportional to the number of observations, a result which indicates that no undue constant errors influence the result. The accordance among themselves of the values for the easterly hour angles is somewhat better than the corresponding values for the westerly hour angles, a circumstance which seems to connect with another phenomenon to be mentioned presently. Giving, therefore, double weight to months of the hourly series, the lunar diurnal variation resulted as given above. When expressed analytically it takes the form—

$$\Delta_{☾} = +\ 0'.001 + 0'.029 \text{ sin. } (\theta + 295^\circ) + 0'.207 \text{ sin. } (2\,\theta + 85^\circ)$$

which may also be written—

$$\Delta_{☾} = 0''.0 + 1''.7 \text{ sin. } (15n. + 295^\circ) + 12''.4 \text{ sin. } (30n. + 85^\circ)$$

where θ represents the moon's hour angle reckoned from the upper culmination, or n, the number of hours after the same epoch, + indicates west and — east deflection.

The constant in Bessel's formula comes out zero, and hence it is inferred that the moon has

no specific action in deflecting the magnet by a constant quantity. The coefficient of the first term of the formula is small, and it is from the second term that the distinctive features of the double-crested curve result. These results are all represented by curves.

Both the east and west deflections are well marked, those occurring when the moon is east of the meridian being greater than those when west.

It is not at all necessary to take in the third or higher terms. The progression of the hourly values is systematic, and the agreement between the computed and observed values is deemed satisfactory.

Diagram No. 2 of Sketch No. 7 represents the curve resulting from the above equation, the observed values being indicated by dots.

The principal western maximum occurs six minutes after the lower culmination of the moon, and amounts to 0′.23. The secondary maximum occurs fourteen minutes after the upper culmination, and amounts to 0′.18. The principal minimum occurs at 6*h.* 17*m.* after the lower culmination, the easterly deflection being 0′.22. The secondary minimum at 6*h.* 03*m.* after the upper culmination, with a deflection of 0′.19. The greatest range is 27″ and the secondary 22″. The epochs of the maxima and minima are found from the formula to be at a mean ten minutes after culmination. The probable error of a single computed value of the lunar declination is $\pm$ 1″.32. The Toronto observations gave $\pm$ 1″.37 from more than twice the number of observations, so that the Philadelphia results are worthy of every confidence.

At Toronto, from the second investigation, embracing about 44,000 observations, the western and eastern deflections balanced, giving for the range 38″.3. The Prague observations also confirm the nearly equal deflections (mean) to the west and east. The epochs of the maxima and minima were found from the four roots of the equation $0 = 0.029 \cos. (0 + 295°) + 0.414 \cos. (2\,\theta + 85°,)$ which gave ten minutes as the mean time elapsed between the moon's passing the meridian and the time of maxima deflections. If we take the four phases into account the lunar action seems to be retarded ten minutes, which quantity may be termed the *lunar-magnetic interval* for the Philadelphia station. At Toronto the intervals are not so regular.

The secondary range exists at Toronto, and is a marked feature in the Prague result. The following table contains the observed and computed values and their differences:

		Obs'd.	Comp'd.	Diff.			Obs'd.	Comp'd.	Diff.			Obs'd.	Comp'd.	Diff.
	h.	′	′	′		*h.*	′	′	′		*h.*	′	′	′
U. C.	0	+0.19	+0.18	+0.01		8	−0.15	−0.09	−0.06		16	−0.10	−0.08	−0.02
	1	+0.17	+0.17	0 00		9	+0.01	+0.01	0.00		17	−0.18	−0.18	0.00
	2	+0.05	+0.10	−0.05		10	+0.10	+0.12	−0.02		18	−0.26	−0.22	−0.04
	3	+0.04	+0.01	+0.03		11	+0.19	+0.20	−0.01		19	−0.19	−0.21	+0.02
	4	−0.10	−0.09	−0.01	L. C	12	+0.29	+0.23	+0.06		20	−0.12	−0.14	+0.02
	5	−0.14	−0.16	+0.02		13	+0.19	+0.21	−0.02		21	+0.01	−0.05	+0.06
	6	−0.19	−0.19	0.00		14	+0.13	+0.13	0.00		22	+0.04	+0.06	−0.02
	7	−0.14	−0.17	+0.03		15	+0.06	+0.03	+0.03		23	+0.12	+0.14	−0.02

The formula or curve enables us to divide the observed values so as to show the diurnal and semi-diurnal part of the observed variations. The decomposition of the curve is made on the diagram where the resulting curves for the diurnal and semi-diurnal periods are given.

The lunar-diurnal variation seems to be subject to an inequality, depending on the solar year, for the investigation of which the preceding results were rearranged in two groups: one containing the hourly values for the summer months, (April to September,) the other the values for the winter months, (October to March.) For the summer season we have 11,087 observations, and for the winter 10,557.

Hourly sums of the lunar variation for the summer season.

MOON'S HOUR ANGLE.

	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
Σ 1840–3..........	+ 9.29	+14.15	+ 3.45	+ 7.20	— 2.93	— 2.23	—15.73	— 6.18	—12.04	— 4.57	— 1.49	+12.38
Σ 1844–5..........	+ 8.62	+ 8.26	+ 3.92	+ 3.95	+ 0.05	— 4.36	— 4.64	— 4.87	— 3.81	— 3.87	+ 1.51	+ 2.13
$\frac{\Sigma}{40}$..............	+ 0.66	+ 0.77	+ 0.28	+ 0.38	— 0.07	— 0.27	— 0.63	— 0.40	— 0.49	— 0.31	+ 0.04	+ 0.42
Same in arc........	+ 0′.30	+ 0.35	+ 0 13	+ 0.17	— 0.03	— 0.13	— 0.28	— 0.18	— 0.22	— 0.14	+ 0.02	+ 0′.19

	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Months.
Σ 1840–3..........	+17.02	+11.44	+ 5.18	+13.14	— 4.94	— 7.97	—16.72	—10.27	—12.44	+0.11	—5.49	+10.12	22
Σ 1844–5..........	+ 4.62	+ 3.32	+ 2.51	+ 0.44	+ 0.10	— 4.85	— 6.88	— 5.47	— 6.18	—4.17	+2.04	+ 1.61	9
$\frac{\Sigma}{40}$..............	+ 0.66	+ 0.45	+ 0.26	+ 0.35	— 0.12	— 0.44	— 0.76	— 0.53	— 0.62	—0.21	—0.04	+ 0.33	
Same in arc.	+ 0′.30	+ 0.20	+ 0.12	+ 0.16	— 0.05	— 0.20	— 0.34	— 0.24	— 0.28	—0.09	—0.02	+ 0′.15	

Hourly sums of the lunar variation for the winter season.

MOON'S HOUR ANGLE.

	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
Σ 1840–2..........	+ 6.42	+ 1.21	+ 4.92	+ 3.04	+ 1.19	— 3.00	— 1.92	— 8.98	— 8.15	— 1.31	+ 1.02	— 6.76
Σ 1843–5..........	+ 0.50	— 1.27	— 3.23	— 5.93	— 7.67	— 5.30	— 3.27	— 0.34	+ 1.02	+ 7.36	+ 7.51	+ 11.18
$\frac{\Sigma}{39}$..............	+ 0.19	— 0.04	— 0.04	— 0.23	— 0.36	— 0.35	— 0.22	— 0.25	— 0.16	+ 0.35	+ 0.41	+ 0.40
Same in arc....	+ 0′.09	— 0.02	— 0.02	— 0.10	— 0.16	— 0.16	— 0.10	— 0.11	— 0.07	+ 0.16	+ 0.18	+ 0′.18

	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Months.
Σ 1840–2......	+ 6.09	+ 0.09	+ 2.31	— 4.18	— 7.95	— 4.79	— 4.79	— 1.85	+ 4.31	+3.86	+8.46	+5.35	15
Σ 1843–5..........	+ 8.62	+ 7.34	+ 5.02	+ 0 70	— 2.73	— 4.62	— 5.32	— 4.82	— 0.65	+2.75	0.00	+1.05	12
$\frac{\Sigma}{39}$..............	+ 0.60	+ 0.38	+ 0.32	— 0.07	— 0.35	— 0.37	— 0.40	— 0.29	+ 0.08	+0.25	+0.22	+0.19	
Same in arc..	+ 0′.27	+ 0.17	+ 0.14	— 0.03	— 0.16	— 0.17	— 0.18	— 0.13	+ 0.04	+0.11	+0.10	+0′.09	

Expressed analytically, the lunar diurnal variation in the two seasons is as follows:

In summer, $\underset{☾}{\Delta} = -\,0'.006 + 0'.028 \sin. (\theta + 18^\circ) + 0'.278\ (2\,\theta + 67^\circ.)$

In winter, $\underset{☾}{\Delta} = +\,0'.005 + 0'.058 \sin. (\theta + 264^\circ) + 0'.173\ (2\,\theta + 115^\circ.)$

The characteristic feature of the annual inequality in the lunar-diurnal variation is therefore a much smaller amplitude in winter than in summer. Kreil, indeed, inferred from the ten-year series of the Prague observations that in winter the lunar-diurnal variation either disappears or is entirely concealed by irregular fluctuations, requiring a long series for their elimination. The method of reduction which he employed was, however, less perfect than that now used. The second characteristic of the inequality consists in the earlier occurrence of the maxima and minima in winter than in summer. The winter curve precedes the summer curve by about one and three quarter hours. Both these features are well expressed in the diagram

No. 7. At Toronto the same shifting in the maxima and minima epochs was noticed, but the other inequality in the amount of deflection is not exhibited. It seems probable that the Philadelphia results are more typical in form than those either of Prague or Toronto. It is also apparent that the smaller deflection at the upper culmination in the annual mean, when compared with the deflection at the lower culmination, is entirely produced by the feeble lunar action in winter. The maximum west deflection in summer occurs actually near the upper culmination. At the same season the maximum east deflection is still retained (as in the annual curve) about six hours after the lower culmination. In the winter season this last-mentioned maximum east deflection is actually the smaller of the two. We have—

Maximum summer range	35″.4,	secondary	31″.8
Maximum winter range	25″.2	do	15″.6
Difference	10″.2		16″.2

At Prague the maximum summer range was 44″.

Next I proceed to examine whether the phases of the moon, the declination or parallax, have any sensible effect upon the magnetic declination. Mr. Kreil found, from a ten years' series of observations at Prague, that there was no specific change in the position of the magnet depending upon the moon's phases and parallax, but that the declination was 6″.8 greater when the moon was at the greatest northern declination than when at the greatest southern declination. On the contrary, Mr. Brown, from the Makerstown observations, a much shorter series than the one at Prague, inferred that there was a maximum of declination two days after the full moon. He also found a maximum corresponding to the greatest northern declination of the moon, but does not appear to have investigated the effect of distance. The residuals which we have been treating enable us at once to examine these several points.

Beginning with the lunar phases, the daily means for the day of full and new moon and for two succeeding days were compared with the monthly mean declination. In case any of the hours were disturbed, the monthly normal for the hour was substituted for the disturbed observation before the mean was taken. If one-half, or more, of the hourly readings were disturbed, the daily mean was altogether omitted. Accidental omissions of hourly observations were supplied by the hourly normal. The half-monthly normals were also used in the comparison. In the table of differences thus formed, equal weight is given to the bi-hourly and hourly observations. The daily mean having been subtracted from the month, the positive sign indicates a western deflection, and the negative sign an eastern one, as compared with the normal position. The following table contains the result:

	Sum of deflection.	Number.	Deflection.		
			d.	′	′
Full moon ☉	+11.6	52	+0.22	+0.10	±0.07
First day after	− 7.1	51	−0.14	−0.06	
Second day after	− 9.3	48	−0.19	−0.08	
New moon ●	−11.5	43	−0.27	−0.12	±0.09
First day after	+ 1.5	47	+0.03	+0.01	
Second day after	+ 4.4	49	+0.09	+0.04	

The effect is very small, scarcely much beyond the probable error, but the table indicates that the north end of the magnet is deflected to the westward 0′.1 at the full, and as much to the eastward at the change day, the range between full and new moon being 0′.2. A more definite

result could hardly have been expected from a series of observations extending over but five years.

Treating the subject of the effect of the moon's variation in declination in precisely the same manner we obtain the following result:

	Mean deflection.				
One day before	— 0'.20,	from	54	days of	observation.
At moon's maximum declination	— 0'.10	"	53	"	"
One day after	— 0'.09	"	55	"	"
Mean	— 0'.13	"	162	"	"
One day before	— 0'.04	"	54	"	"
At moon's minimum declination	— 0'.07	"	52	"	"
One day after	+ 0'.14	"	52	"	"
Mean	+ 0'.01	"	158	"	"

These results do not positively fix a deflection of the magnet as depending on the moon's greatest north and south declination, the amount resulting from the comparisons being of nearly the same magnitude as its probable error.

A similar investigation with respect to the moon's distance from the earth gives the following results:

	Mean deflection.				
One day before	— 0'.18,	from	50	days of	observation.
At moon's perigee	— 0'.18	"	41	"	"
One day after	0'.00	"	59	"	"
Mean	— 0'.12	"	150	"	"
One day before	— 0'.02	"	55	"	"
At moon's apogee	— 0'.20	"	53	"	"
One day after	— 0'.13	"	47	"	"
Mean	— 0'.12	"	155	"	"

The differences being of the same order of magnitude as the probable errors, no conclusion as to the effect of distance can be drawn from them.

I propose hereafter to extend the discussion of the moon's effect on the declination to the effect on the earth's magnetic force.

APPENDIX No. 25.

Results of observations made on solar spots during the first seven months of the year 1860, *by C. A. Schott, Assistant in the Coast Survey.*

COMPUTING DIVISION, COAST SURVEY OFFICE,
August 15, 1860.

DEAR SIR: The apparent connection between certain variations in terrestrial magnetism and the variations in the activity of the sun for the productions of solar spots, discovered nearly

simultaneously and independently in 1852 by Sabine, Gautier, and Wolf,* principally from the magnetic results of Lamont and the solar spot observations of Schwabe, made it desirable that observations of the solar spots should be made in co-operation with the magnetic observations now in progress at the stations Key West, Florida, and Eastport, Maine. As an illustration of the above connection, Part I of the discussion of the magnetic observations at Girard College, Philadelphia, in 1840 to 1845,† may be referred to. In that paper the relation subsisting between the frequency of the solar spots and the law of the disturbances and the changes in the amplitude of the solar diurnal variation of the magnetic declination is fully discussed.

In accordance with your instructions, I commenced daily observations for frequency and position of the solar spots on January 1, 1860, at one of the Coast Survey office buildings, in latitude 38° 53′ 04″.2, longitude 77° 00′ 10″.7, west of Greenwich. The observations for position were made, as weather permitted, in the manner described by Mr. Carrington, and explained in the monthly notices of the Astronomical Society.‡ The observations were made with an equatorially mounted Fraunhofer and Utzschneider telescope of four feet focal length, having an object glass three inches in diameter. The magnifying power used was 55. The image of the sun was received on a screen, of a light neutral bluish tint, attached to the inside of a box fastened to the eye end of the telescope, and open on one side. The projected image was nearly five inches in diameter. To identify the spots from day to day a sketch was traced by the eye by slipping a sheet of paper over the screen, a more elaborate drawing being made afterwards of all the more remarkable spots (and faculæ) with the higher magnifying power of about 175. The contacts and transits of the spots over the wires were noted with the mean time chronometer, "Kessel's, No. 1287." In these observations I was assisted by Mr. J. H. Patton. The computations for heliographic latitude and longitude of the spots are in progress. In the present report I give (as a first result) a table of the relative frequency of the solar spots for the first seven months of the present year. The sketches generally were made between one and two o'clock p. m., Washington mean time.

The principal solar spot period discovered by Prof. R. Wolf, and fixed by him at 11.11 years, (with a mean error which may be estimated according to Mitth. IX at ± 0.3 years,) is plainly exhibited by means of a proper system of enumeration known as Wolf's relative numbers of the frequency of the solar spots. A large mass of observations have been carefully registered in accordance with this enumeration; and lately§ Mr. Carrington prepared a map on which the maxima and minima of the frequency of the solar spots between the years 1740 and 1860 were laid down; the ordinates being projected throughout by the relative numbers of Prof. Wolf. The nature of these numbers may be briefly explained, as follows:‖ The activity of the sun in producing solar spots being directly proportional to the number and area of the groups and single spots may be expressed by $a = mg + ns$; where $g =$ number of groups, $s =$ number of spots, and m and n co-efficients or relative weights. According to Prof. Wolf's investigation, $m = 10$, $n = 1$, or $a = 10\,g + s$. Hence we obtain the relative numbers by adding the number of single spots (those forming groups as well as those of an isolated character) to ten times the number of groups. The only difficulty in this enumeration lies in the definition of a group or assemblage of spots apparently connected; but owing to the circumstance that

* Wolf, Mittheilungen über die Sonnenflecken, I and III. Zurich, 1856–'59.

† See Smithsonian Contributions to Knowledge, Vol. XI, 1859; also Coast Survey Report for 1859, Appendix No. XXII. Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, 1845, Part I. Investigation of the eleven-year period in the amplitude of the solar diurnal variation, and of the disturbances of the magnetic declination, by A. D. Bache, LL.D.

‡ Monthly Notices, Vol. XIV, No. 5, 1854, and Vol. XV, No. 6, 1855. The formulae as given in the second paper were adopted.

§ Monthly Notices Astronomical Society, No. VII, May 11, 1860.

‖ See Wolf's Mittheilungen, No. I and No. VI.

there is a strong tendency to the formation of groups, any two observers, after acquiring the necessary experience, will probably not materially differ in their average numbers. The final numbers will require a multiplier depending on the power of the telescope used. In the present case this factor must be near unity, since the magnifying power does not differ much from that used by Schwabe and Wolf.

In the following table the first column of each month contains the number of groups, and the second column the total number of spots; the mean numbers of relative frequency or activity are at the bottom.

1860.	January.		February.		March.		April.		May.		June.		July.	
	g.	s.	g.	s.	g.	s.	g.	s.	g.	s.	g.	s.	g.	s.
1	3	5	7	22	6	19	......	......	......	......	......	......	......	......
2	7	19	......	......	7	21	4	8	......	......	7	19	......	......
3	......	......	8	19	......	......	......	......	10	20	......	......	12	31
4	8	22	9	30	......	......	......	......	8	21	6	15	13	24
5	8	21	......	......	6	8	4	6	10	19	......	......	11	21
6	3	7	......	......	8	14	3	6	10	24	5	12	7	7
7	......	......	7	23	7	15	4	13	9	18	4	12	......	......
8	......	......	......	......	......	......	4	10	6	14	6	11	......	......
9	5	9	7	27	8	26	7	26	......	......	6	11	6	18
10	......	......	5	24	......	......	......	......	......	......	......	......	5	10
11	4	6	......	......	......	......	......	......	......	......	7	11	4	8
12	......	......	......	......	......	......	5	17	7	17	5	10	......	......
13	......	......	5	19	5	10	5	14	7	10	6	15	4	7
14	......	......	......	......	8	21	......	......	5	11	5	9	4	10
15	......	......	......	......	8	15	5	7	6	11	6	9	......	......
16	6	9	3	12	5	9	......	......	7	11	4	5	5	7
17	4	13	4	15	5	11	5	10	5	9	......	......	4	5
18	6	12	......	......	......	......	4	10	5	12	6	12	5	10
19	6	14	......	......	......	......	......	......	5	10	6	12	......	......
20	6	18	4	10	3	8	......	......	......	......	......	......	7	11
21	6	16	4	9	4	9	4	11	8	19	......	......	8	11
22	6	16	......	......	4	6	......	......	......	......	8	13	......	......
23	6	11	3	9	6	8	......	......	8	21	10	25	11	17
24	6	10	......	......	7	9	5	10	9	19	......	......	13	20
25	6	18	5	15	......	......	......	......	9	19	12	30	12	23
26	......	......	......	......	10	21	4	9	10	19	12	37	11	16
27	......	......	7	17	9	23	4	9	......	......	12	42	12	29
28	4	13	5	18	9	20	......	......	9	15	11	48	13	32
29	......	......	6	17	8	20	6	14	6	11	13	45	......	......
30	5	20	......	......	9	19	4	7	......	......	14	34	......	......
31	......	......	......	......	9	18	......	......	7	21	......	......	9	19
Mean	68.4		73.5		83.6		56.3		91.4		97.6		99.8	

Yours, very respectfully,

CHARLES A. SCHOTT, *Assistant Coast Survey.*

Professor A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 26.

Report on the magnetic station at Key West, Florida reef, by Prof. W. P. Trowbridge, Assistant Coast Survey. (Sketches Nos. 23 and 24.)

UNITED STATES COAST SURVEY OFFICE,
Washington, May 1, 1860.

DEAR SIR: I have the honor to present the following account of the establishment of the magnetic station at Key West, Florida, to which duty I was assigned by your instructions of December last.

The instruments intended for the observatory were sent to Norfolk in charge of the observer, Mr. Samuel Walker, on December 13, 1859, packed in twelve boxes. At Norfolk they were shipped on board the Coast Survey steamer Walker, bound to the Gulf of Mexico, and were safely landed at Key West on January 10, 1860.

I arrived at Key West on the 8th of January, and was therefore ready to receive the instruments, for which I procured temporary storage in Fort Taylor, through the kindness of Capt. E. B. Hunt, U. S. Engineers, in charge of the fort. I was much indebted to Lieut. Comg. Guthrie, of the Walker, and Lieut. Comg. Wilkinson, of the Corwin, for their kindness in transporting the materials and instruments safely to Key West, and in landing them for me in their boats at Fort Taylor.

Two temporary buildings belonging to the fort had been offered for our use by the Engineer department, and the first step to be taken was to examine these buildings to ascertain whether either would answer the desired purpose. That which appeared most promising was an old magazine, built originally in a very substantial manner, and entirely free from iron, all the fastenings being of copper. After a very thorough study of the plan of the required observatory, and a close examination and measurement of this magazine, it was found to be entirely too small, being not only deficient in the ground plan, but also in height. It was moreover, insecure, the lower timbers having been almost destroyed by dry-rot. The other building was merely a large shed, built for a cement shed. This building presented a clear ground area of 60 feet by 21 feet, with a height of 10 feet to the pitch of the roof. It was well roofed and weather-boarded, with double folding-doors at the ends. As the locality seemed favorable, I decided to make use of this shed as an outer covering and protection, and to construct a close room within it for the instruments, leaving a clear space between the walls of the two for the circulation of air. By allowing a free circulation, and at the same time having the interior room protected from the direct rays of the sun, the necessary conditions for steadiness of temperature would be obtained, though the walls were not thick. This arrangement allowed several feet of air space between the roofs of the inner and the outer buildings.

The building having been decided upon, observations were made to determine the bearings of the sides with reference to the magnetic meridian, the result of which was that the longest walls, which were north and south, were one foot four inches out of the magnetic meridian in their whole length of 59 feet. This permitted the placing of the piers within the inner building according to the plan adopted. Detailed drawings were then made showing the positions and dimensions of the piers, from which their positions were laid off carefully on the ground. Excavations were then made down to the solid rock, and after the positions of the piers had been verified by additional observations for the magnetic meridian, they were built up with bricks and hydraulic cement in the most substantial manner. The height of each pier was determined before the lower course was laid, so that the workmen might bring them up with even courses, and without cutting the bricks. Earth was then thrown around the bases of the piers, filling up the excavations, and the ground prepared for the floor timbers.

The interior room was laid out according to a plan already prepared. The dimensions are 17 feet by 31 feet; ten feet of the south end being partitioned off for the operating room.

The room was made of such a size that no instrument would be nearer than 18 inches to the wall, thus allowing the observer to pass around the piers without knocking against them. The floor, sides, and ceiling were made of tongued and grooved pine boards, planed on the inner side and fastened with zinc nails. A very close, clean room was thus formed, by which the instruments as well as the paper and chemicals are protected from currents of air or dust. The strength of the construction is such that walking about produces no sensible vibration in the building. The piers are of course not connected with the floor, a space of half an inch being left around each pier.

The instruments placed in the instrument room (Sketch No. 23) for the continuous record of

the magnetic variations are the following, viz: The *Declinometer*, the *Horizontal Force Magnetometer*, the *Vertical Force Magnetometer*, one *Clock and Recording Apparatus*, for the first two instruments, and one *Clock and Recording Apparatus* for the vertical force instruments. There are also three tripods for supporting the lamps, one in front of each magnet.

These instruments may be described as follows: The Declinometer consists essentially of a tripod stand from which a flat bar magnet is suspended by a silk suspension thread. The tripod is composed of a black marble base $16 \times 19\frac{1}{4}$ inches, and $1\frac{1}{4}$ inches thick. Six legs formed of brass tubes about three-quarters of an inch in diameter screwed to bolts passing through the corners of the slab, a heavy circular plate to which the legs are screwed at top; a torsion plate resting upon this, which carries a suspension hook and elevating screw, the suspension skein, and the magnet and its attachments. The torsion plate carries a vernier, and the plate upon which it rests is graduated to read, with the vernier, to half minutes.

The suspending skein is formed of thirty single fibres of raw silk, which were originally stretched by equal weights to each fibre, and then bound together while stretched, at intervals of a few inches. The aggregate of the weights being equal to the weight of the magnet and attachments. The maximum strength and minimum torsion are thus secured, while the skein has a large surplus strength over the breaking weight.

The magnet and attachments comprise all that is suspended by the skein. The magnet is inserted between two small plates with screws passing through the corners of the plates by which the magnet is clamped in its place. A hook is attached to the centre of the upper plate which hooks into the loop at the end of the skein. To the lower plate is attached a light brass frame which sustains a circular reflector, $2\frac{1}{2}$ inches in diameter, in a vertical position below the magnet; the distance from the centre of the reflector to the central line of the magnet being $2\frac{1}{4}$ inches. The reflector is concave, having a focal length of 8 feet 6 inches. Below the speculum, and attached to the same frame, is a small rectangular mirror of plane glass, fixed in vertical position by screws. The large mirror reflects the light of the lamp to the photographic register, and the small mirror reflects the scale of a fixed reading telescope (placed in any part of the room) by means of which the direction of the magnet may always be referred to a fixed line.

The pier upon which this instrument rests is 3 feet $6\frac{3}{4}$ inches above the floor and 20 inches square in horizontal section.

The lamp which properly forms a part of the Declinometer apparatus rests upon a tripod at a distance of about 2 feet from the centre of the speculum, and near the line joining the speculum and the mean position of the trace on the recording cylinder; the tripod stands upon a pier which rises one foot from the floor. The light from the lamp passes through a narrow slit in an upright strip of metal, and, falling upon the speculum, is reflected to the recording cylinder. A dark shade stops all the light of the lamp except that which passes through the slit.

The horizontal force magnet is supported on a pier near the corner of the room, diagonally opposite to the declinometer. The marble slab for the base of the tripod, the tripod, the torsion circle, and the elevating screw, correspond to the similar parts of the declinometer. In both instruments the suspension skeins are protected by glass tubes, through which the skeins pass, and the magnets and attachments are protected by glass cases resting upon the marble slabs; so that when the magnets are finally adjusted they are not deranged by currents of air or dust. A small glass case is placed upon the top of each instrument, fitting closely to the plate, for the same purpose. The only essential difference in the construction of the two instruments is the double or bifilar suspension skein of the horizontal force apparatus and its temperature-compensating apparatus. The silk suspension skein is made like that of the declinometer, but the magnet is suspended by passing the skein over a glass roller attached to the elevating screw, the two ends falling down through the glass tube to the small suspension hooks of the magnet and its attachments. The magnet has nearly the same dimensions as the

declinometer magnet, and the mirrors are attached in the same manner, having the same office to fulfil. The temperature compensating attachment of this magnet is fixed to the upper plate, which holds the magnet in its place. This compensating apparatus consists of the following arrangements, viz: A small glass rod, about ten inches in length, is clamped at its middle point to the top plate of the two, between which the magnet is clamped, and in the direction of the magnet; two separate zinc tubes, each about half the length of the rod, are then slid over the ends of the glass rod, the rod being kept in the middle of the tubes by interior rollers. The tubes may be clamped to the rod at the ends furthest from the centre of the magnet, or at the end nearest the centre. The loops of the suspension thread are hooked to the ends of the zinc tubes, near the middle of the glass rod. The temperature compensation is effected by clamping the zinc tubes to the glass rod at the extreme end, thus allowing the *tubes* to expand towards the centre, while the expansion of the *glass rod* is from the centre.

The magnet being adjusted in its position perpendicular to the meridian by means of the torsion, if we suppose the temperature to rise, the force of the magnet becomes less, and the torsion force preponderates; the ends of the glass rods expanding outwards at the same time, the lower interval of the threads is increased, and the torsion force thus increased; but the expansion of the zinc being in the opposite direction, and being greater than that of the glass, the lower interval is, in fact, lessened; so that the same cause which tends to weaken the force of the magnet weakens also the torsion force, and the equilibrium of the two forces remains unaffected by this cause. The proper adjustment of this compensation is a very difficult matter, and, as will be seen subsequently, the attempt to adjust it at Key West was abandoned and the zinc tubes were clamped at the centre. The temperature corrections are, therefore, to be made as in other instruments.

The lamp, lamp stand, and its pier, are constructed in the same manner as those of the declinometer, and similarly placed. As the record of the instruments just described are made on the opposite ends of the same cylinder, the lamps are on opposite sides of the line joining the centres of the mirrors of the two instruments.

The *recording cylinder and clock* for these instruments is placed near the middle of the room upon a brick pier, which rests upon the solid rock below. The object of this clock is to give motion to the cylinder around which the photographic paper is wrapped to receive impressions from the light from the lamps. The clock is a substantial pendulum clock, similar to those used for the self-registering tide gauge. Upright supports are fixed to the base board of the clock, upon which the cylinder axles rest. To the cylinder (a hollow drum with brass plates for the ends) motion is communicated by means of wheel-work, at the rate of one revolution in twenty-four hours. The clock not only serves to give motion to the cylinder, but gives the means of recording the time in connection with the record of the magnetic variations.

The cylinder is $8\frac{3}{4}$ inches in diameter, and 13 inches in length. The pier on which this apparatus stands is of such a length as to allow the pendulum to swing clear of the floor by three inches; and as the central line of the cylinder must necessarily be in the same horizontal plane with the centres of the two mirrors of the magnets, the height of this pier above the floor was first determined, taking into account the length of the pendulum, the thickness of the base board of the clock, and the height of the centre of the cylinder above that board, and the magnet and lamp pier regulated accordingly. The height of the brick-work of the pier is three feet five inches. This pier supports, besides the clock and cylinder, the cylindrical lenses for bringing the light of the lamps to a focus upon the surface of the cylinder. These lenses, one for each magnet, on opposite sides of the cylinder, are each composed of two plain convex lenses twelve inches in length, the outer having a focal length of two and a half inches, the lenses being fixed in a wooden frame about eight-tenths of an inch apart, and the combination having a focal distance of about half of an inch. The lenses are supported on wooden feet, so that the central lines of the lenses shall rest in the horizontal plane of the axis of the

cylinder. Thus, when the instruments are adjusted, the magnets, mirrors, and the lenses on each side, form a combination by which the light of each lamp, reflected from its mirror, is brought to a focus at a point upon the surface of the cylinder, in whatever direction the magnet may point within the limits of the ordinary variations.

The declinometer and bifilar magnets are about 19 feet 5 inches apart, the recording cylinder being nearly the same distance from each. The exact measurements are given in another part of this report.

The central clock pier supports also the fixed telescopes and scales to be employed as checks upon the photographic registers. For the purpose of obtaining perfectly fixed supports for these telescopes the central pier was corbelled out on two sides, beyond the dimensions required for the clock and cylinder, and the telescopes firmly fastened upon these corbels.

The vertical force magnetometer is placed near the NW. corner of the room, about twelve feet from the horizontal force magnet. This instrument consists, essentially, of a bar magnet, of nearly the same length and breadth as the other two magnets; the attachments of the magnets, (viz: the frame and mirrors,) *the marble base*, and supports for resting the magnet frame upon agate planes. While the declinometer and horizontal force magnets are suspended by torsion skeins of silk, and move in horizontal planes, the vertical force magnet vibrates in a vertical plane upon a horizontal axis. The frame is provided with agate knife edges which rest on agate planes, and the magnet is balanced in such a manner as to vibrate under the influence of the vertical component of the magnetic force. The centre of the speculum is nearly in the axis of rotation, while the small mirror for the fixed telescope is above the axis. Both are attached to the frame by clamp-screws, as in the other instruments. The lamp and its stand correspond to those of the other instruments, and are placed at the same distance, nearly, from the magnet.

The clock and cylinder for the photographic record of this instrument are placed in a line perpendicular to the magnetic meridian from the magnet, and at about nine feet two inches from it. This places the clock near the horizontal force magnet pier, though it has no connection with it. The cylinder is vertical and revolves under the influence of the clock-work once in twenty-four hours. The lens for concentrating the rays is, of course, vertical. The magnet, lamp, and clock are placed on separate piers. The reading telescope is placed on the clock pier. The vertical force magnet is protected from currents of air, dust, &c., by a close box with glazed openings for the light of the lamp to pass through to and from the mirrors.

These comprise all the instruments employed for the continuous record of the magnetic variations. The foregoing description is only intended to be general in its character, as a more detailed description of the instruments can only be given with the aid of drawings; but I have presumed that a brief general description would not be out of place in this report, though the construction and use of the instruments are known to those who take a special interest in the subject.

Before mounting the instruments the room was thoroughly cleaned and dusted and the piers yellow-washed.

The declinometer and horizontal force magnetometer were first unpacked and placed, approximately, in their respective positions. The central clock and cylinder were then placed in position and the three instruments adjusted, approximately, to their respective heights, so that the axis of the cylinder, and the centres of the large mirrors of the magnets, should rest in the same horizontal plane. As the magnets, when finally adjusted, are enclosed in rectangular glass cases it is important that the faces of the glass through which the light passes should be perpendicular to the rays, this requires the adjustment of the marble bases with reference to the magnetic meridian; which was accomplished by marking points on the walls in the magnetic meridian and stretching a fine thread between these points, by which the slabs were set in their proper directions. The same method was taken to determine, finally, the

relative positions of the magnets before securing the slabs to the piers, it having been determined to place the declinometer and horizontal force magnets so that the line adjoining their centres should make an angle of 35° 16′ with the magnetic meridian.

The piers were found to be of the proper relative heights and the marble slabs were then laid in cement and perfectly levelled before the cement had time to set.

The central clock was secured to its pier by large screws let into a heavy square block which was set with the mortar in the top course of masonry.

The lamps were set and adjusted in the same horizontal plane with the centres of the mirrors and the axis of the recording cylinder.

The lamp stands were not fastened to their piers until a final adjustment of the focal distance could be made.

The vertical force instrument was then unpacked and mounted, the marble base being firmly set in cement, and great care being taken to place the magnet in a position perpendicular to the magnetic meridian. This was accomplished by stretching a fine thread in the magnetic meridian and adjusting the line of knife edges to this thread. Especial attention was paid to levelling this instrument also.

The clock and cylinder apparatus for the vertical force instrument was then placed upon the pier destined for it, levelled, and permanently secured by heavy brass screws. The frames holding the lenses for this cylinder, as well as those for the other instruments, were secured to the base boards by stops, in such a way as to permit of their being easily adjusted or removed, and secure from accident.

The reading telescopes of the declinometer and horizontal force magnets were placed on corbels run out on opposite sides of the central pier, and firmly secured by wooden clamps. The telescope for the vertical force magnet was placed on its clock pier, one course of brick being carried up a few inches to give it the proper height. Additional strength and firmness was given to this projection by strips of boards nailed to the pier, and the telescope fastened to a cross strip by screws. The reading telescopes were thus fixed as permanently as the piers, and all the instruments being thus placed upon solid masonry, disconnected with the building, and resting upon solid rock, permanence and stability were secured.

Very little wood-work was attached to the masonry, and wherever it was necessary the best seasoned pine was used.

The instruments were all thoroughly cleaned before being mounted.

Adjustments.—The adjustment of the declinometer first engaged my attention. The adjustment of this instrument consists, first, in bringing the line of no torsion to coincide with the mean magnetic meridian; second, the adjustment of the speculum in azimuth and vertically, so that when the magnet is at rest the light from the lamp will be reflected to the required point on the surface of the recording cylinder, when the lamp is fixed in its proper position; third, the adjustment of the small mirror in azimuth, and the reading telescope in height, so that the scale attached to the telescope can be read plainly through the telescope; fourth, the adjustment of the cylindrical lens, to bring the rays to a focus on the surface of the cylinder.

The first adjustment is made in the usual manner, by suspending a leaden bar, of the same weight as the magnet, in the magnet frame, and adjusting the line of detorsion by successive trials. The second adjustment is combined with the adjustment of the lamp. The latter is first placed so that the angle of the incident and reflected rays shall be as small as possible, and at such a focal distance from the speculum that the rays will be brought to a focus in the focus of the cylindrical lens. The manner in which the speculum is supported renders this a difficult adjustment; it is moved in its frame by clamp and tangent screws, which in the instrument employed are not well adapted to the purpose; and it was only by patient and long-continued trials that the adjustment could be made. And when to this adjustment is added the third, which must be simultaneous with it, the whole operation became very perplexing and tedious;

especially when it is necessary that the final touch of the screws must leave the mirror and magnet firmly and permanently clamped in their places, and when the slightest excess of motion throws them out of place. The instruments in this respect might be greatly improved.

The adjustment of the lenses is not difficult. The frame holding them should be placed at such a distance from the cylinder as to bring the light to a well-defined focus upon the surface and in the plane of the axis.

The only source of uncertainty in a long continued series of observations with the declinometer is the possible change of the magnetic axis of the magnet, with the permanent loss of magnetism which gradually takes place. With a mounting adapted to a reversal of the magnet, the magnetic axis might be determined from time to time.

Adjustment of the horizontal force magnet.—The adjustments of this instrument are the following, viz: 1st. To place the magnet, by means of the bifilar torsion suspension, perpendicular to the magnetic meridian. 2d. To adjust the mirrors so that the reflected rays from the lamp and telescope scale shall fall respectively on the surface of the recording cylinder and the reading telescope when the magnet is in its position, perpendicular to the magnetic meridian. 3d. The adjustment of the focal distances of the lamp and the cylindrical lens. 4th. The adjustment of the temperature compensating apparatus by artificial changes of temperature of the magnet and its attachments.

The first adjustment was made by stretching two fine threads across the room, directly over the suspended magnet, in the direction of and perpendicular to the magnetic meridian. The magnet frame was suspended first, with a lead bar in place of the magnet, and the line of no torsion was adjusted to each of these threads in succession, and the readings of the torsion taken, showing a difference of 90°. The magnet was then inserted with marked end east, and the torsion circle turned in azimuth until the direction of the magnet coincided with the line perpendicular to the magnetic meridian, the lower interval of the threads being determined, so that the torsion angle should be large enough to render the torsion force sensitive, and yet without rendering the equilibrium between the torsion and magnetic forces unstable. The magnet was then reversed, and the same determinations made with marked end west, and a mean of the result taken. The same determinations were made with the marked end west.

The adjustments of the mirrors and lamps correspond to the same adjustments in the declinometer, the same difficulties, except in a greater degree, being experienced from the mode of attaching the magnet and mirrors to the suspension frame. The suspension skein was well stretched before the final adjustments were made.

The adjustment of the temperature-compensating apparatus of Mr. Brooke was found to be impossible under the large horizontal force at Key West. This compensation depends upon the horizontal component of the magnet force of the earth, the magnetic moment of the magnet, the weight of the magnet and its attachments, the upper and lower intervals of the threads, the length of the threads, and the angle of torsion, and is determined experimentally, with the aid of the following formulæ:

$$m.\ X = W.\ \frac{ab}{b}.\ \sin\theta.$$

By the arrangement proposed and described in the foregoing pages, *b*, the lower interval of the threads, is made to change with *m*, so that the two members of the equation remain equal under changes of temperature.

The value of X, for London, employed by Mr. Brooke was X = 3,8, and the value of *ab* and *b* were made to correspond, (*m*) (W.) and *sin* θ being supposed to be constant. When it became necessary to put up the instruments at Key West, where the value of X is nearly double that for London, (6,8,) it was found that the value of neither of the quantities *ab*, *b*, sin θ, or W, could be changed sufficiently without a new construction of the instrument. This conclusion was confirmed by the first attempt at comparison by artificial change of temperature.

In the hope of overcoming the difficulty I had an auxiliary roller made of the same dimensions as the suspension roller, to be placed a few inches below the latter, as a spreader; the effect of which would be the same as increasing a as far as the compensation was effected, while the principles and sensitiveness of the torsion balance would remain unchanged. This expedient was tried, and succeeded so far that, by raising and lowering the auxiliary roller, two points were found, at one of which the instrument was over-compensated, and at the other under-compensated; but a new difficulty occurred, which could not be overcome. This was the impossibility of heating and cooling the apparatus with the means at command in such a manner as to make the experiment for a perfect compensation reliable. The atmosphere at Key West is so highly charged with moisture that, when the magnet was cooled much below 67°, there was a copious deposit of dew upon the magnet and its attachments, which, by increasing the weight, rendered the result uncertain; and again, on heating, the moisture was evaporated, producing a similar effect.

From a series of experiments, the results of which are given in the appendix to this report, I found the desired compensation quite impracticable, and was obliged to go back to the old method of observing the temperature of the magnet, and providing for a temperature connection. The small coefficients of the magnets, and the steadiness of the temperature at Key West, will make the temperative connections very small for the daily changes. The temperature coefficient of the horizontal force magnet, as determined by Mr. Brooke, is 0.000507 + .00000243, and for the vertical force magnet 0.0000757 + 0.000000345. By my own determinations it is somewhat larger, as will be seen from my determinations. The mean daily range of the temperature at Key West, for each month, (from the Army Meteorological Register,) for 1851 and 1852, is given below; also the mean monthly range, for each month, for four years, and the mean temperature for each month for fourteen years. From these records it will be seen that the climate of Key West is remarkable for regularity and steadiness of temperature—especially favorable for magnetic observations, in presenting a very small daily range of the thermometer, seldom greater than 5° Fahrenheit, and the monthly variations recurring with remarkable coincidence in the different years.

Mean daily range of temperature for each month, for the years 1851 *and* 1852, *at Key West, and monthly range for four years.*

	1851.				1852.				Monthly ranges for four years.			
	9 a. m.	3 p. m.	9 p. m.	Range.	9 a. m.	3 p. m.	9 p. m.	Range.	1851.	1852.	1853.	1854.
	°	°	°	°	°	°	°	°	°	°	°	°
January	74.2	76.7	73.4	23	63.7	67	63.2	27	23	27	25	22
February	74.8	77.9	75.9	17	70	73.8	69.7	26	17	26	20	17
March	74.3	77.3	73.2	24	75.2	77.9	73.4	22	24	22	19	16
April	77.6	81	75.9	21	76.6	79.6	74.8	20	21	20	16	23
May	80.5	82.6	78.5	82	80.8	84.3	79.8	18	22	18	13	17
June	82.6	84.8	80.3	12	83.2	86.6	82.3	13	12	13	12	12
July	84.2	87.4	82.6	12	84.4	86.6	82.8	12	12	12	12	11
August	84.7	87.3	82.9	15	84.8	87.2	83 3	16	15	16	10	11
September	82	84.2	80.8	12	83.1	84.5	81.5	11	12	11	10	11
October	80.4	83	79.1	14	80	81.8	79	15	14	15	14	12
November	75.9	79	74.5	24	76.4	78.4	76.2	20	24	20	14	25
December	70	73.9	69.5	29	75.2	77.7	74.6	22	29	22	24	26

MEAN MONTHLY TEMPERATURES FOR FOURTEEN YEARS.											
Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
° 66.8	° 68.9	° 72.9	° 75.4	° 79.1	° 81.6	° 83	° 82.9	° 81.9	° 78.1	° 74.7	° 71

The adjustment of the vertical force magnet consists, first, in placing the magnet perpendicular to the magnetic meridian; second, adjusting the mirror and clamp as in the other instruments; third, balancing the magnet on the agate planes so that it shall be sufficiently sensitive under the influence of the vertical action of the magnetic force without being in a position of absolute unstable equilibrium.

The first adjustment is a permanent one, and must be made in setting the marble base. The mirrors are adjusted without difficulty, as the motion is upon the fixed solid axis to which the mirrors are attached. The third is not attended with difficulty, as the more delicate adjustment of the balance is accomplished by small counterpoise weights at the ends of the projecting rods, the weights being moveable upon the rods by fine screw threads. In order to make the balance sufficiently sensitive, however, it is necessary to bring it very near to the position of unstable equilibrium, and as it is impossible for the instrument to have the sensitiveness of the torsion balance, another adjustment is provided for in the instrument put up at Key West, devised by Mr. Brooke, to compensate for the effect of changes of temperature. This is a small thermometer, constructed with great care and skill, to be clamped near its centre of gravity to the axis of motion. The construction is intended to be such that when the magnet is balanced between the opposing forces of gravity and the vertical magnetic force, a change of temperature will cause the mercury in the stem to expand or contract, just enough to overcome the loss or increase of the force of the magnet caused by the same change of temperature. A rise of temperature, for instance, diminishes the magnetic force of the magnet, and the balance is disturbed while the earth's magnetic force may not have changed. The thermometer restores the equilibrium by the expansion of the mercury throwing a little more weight to one side. I am inclined to believe, however, that this compensation is entirely too delicate for the instrument, and that the only reliable way to obtain good results with the balanced magnetometer is to secure it, as completely as possible, from changes of temperature; any considerable change of temperature must affect the balance by the contraction or expansion of the frame and counterpoise rods. As will be seen in the account of experiments on this instrument, given in the appendix to this report, the same difficulty occurred from the deposit of moisture upon the magnet as in the case of the horizontal force magnet. Although different modes of heating were adopted, all attempts to adjust the automatic compensator failed, and any great change of temperature, either way, threw the instruments entirely out of balance. I therefore took every precaution to preserve a steady temperature in the magnet, by wrapping a blanket around the box enclosing it, in addition to the other considerations favorable to this object. A thermometer was placed in the box, to be read through the glazed aperture, for the purpose of recording the temperature.

The instruments mounted at Key West are those designed by Mr. Charles Brooke, of London, and forwarded to this country in 1852. They had previously been mounted at the Magnetic Observatory in the grounds of the Smithsonian Institution. The only important alteration in the original design is the substitution of pendulum clock movements instead of the chronometers employed by Mr. Brooke, and the use of a single wooden cylinder for the record of both the declinometer and bilifar magnets. In Mr. Brooke's arrangement a cylinder and separate sheet for each instrument were employed.

Lamps.—One of the most important considerations in a photographic observatory of this character is to obtain a constant and steady light. In the vicinity of towns lighted with gas this is not difficult; but at Key West no facility of this sort was presented, and I was obliged to make numerous experiments on the character and construction of the lamps to be used.

Several patent gas burners were presented to me, which seemed, at first, to offer the best possible light for the purpose. On the first trials they burnt with a beautiful, steady flame, and gave satisfaction. That which gave the most promise is called the "Vesper Gas Burner." Nothing can be more simple and ingenious than the operation of this burner in converting fluid camphene into vapor by the heat of the burner itself, the vapor being burned as it issues from a small orifice. No doubt was entertained after a trial of several weeks, while the other experiments were in progress, that this burner would answer the purpose fully, and a reservoir was set up outside of the building with small leaden pipes connecting the reservoir with the burner for each instrument. The great advantage of this burner consisted in the alleged fact that the wick needed renewing only once in three or six months. Before it became necessary to set the instruments finally at work, however, it gave indications of irregularity, frequently going out, and requiring almost constant watching. This was caused by the accumulation of resinous matter at the orifice, a fault which cannot be overcome; and I was obliged to seek another kind of burner. Fortunately I found the kerosene lamp at Key West, which, from the testimony in its favor, appeared to be the next best for trial. Several of them were immediately adapted to the instruments with the most favorable results. The flame is much better for photographic purposes than the gas light, having more body, while the wick requires renewal only once in several weeks, and a slight trimming each day. In order to keep the oil up to the wick, a flat zinc reservoir was made, and the burner attached to the top of it. With good oil and ordinary care this lamp is better, I believe, than coal gas light.

The next step, in order, was the determination of the scales for the reading telescope and the registers. The object of these scales is to measure the angular motions of the magnets. If any scale of equal parts be assumed, the angular value of one division will depend on the distance of the scale from the mirror which reflects the light, and may be determined from the expression,

$$a^1 = \frac{21600}{2\,\pi}, \ \frac{b}{r}$$

in which a^1 represents the angular value in minutes of arc of one division, b the length of one division of the scale in inches, and r the distance of the scale from the mirror. But since the angular motion of the mirror is only one-half the angular motion of the reflected ray a, the angular value of the scale is represented in the expression,

$$a = \frac{10800}{2\,\pi}\,\frac{b}{r}\,—$$

$$\text{and from this } b = \frac{\pi}{5400}\ a.\ r.$$

for convenience the length on one division of each scale was made to correspond to one minute of arc, and hence

$$b = \frac{\pi}{5400}, \ r.$$

The distance r for each scale was measured with great care. A measuring bar of seasoned pine, two inches thick and four or five inches broad, was made, the sides and edges being planed true. This was made a few inches shorter than the shortest distance to be measured, and carefully divided into feet by a standard scale; the divisions were numbered from the middle of the bar each way to the ends. A small auxiliary bar was made, about six inches in length, to slide over the ends of the main bar, to measure the fractions of feet, and for greater facility of adjusting the end to the extreme points of the distance to be measured. The bar

was first set up to measure the distance from the centre of the large mirror of the bifilar magnet to the surface of the cylinder on which the photographic trace was to be made. The details of measurement are given in another part of the report. The whole distance was found to be $9\frac{502}{1000}$ feet, and the length of the scale corresponding to one minute of arc 0.0663 inches. In the same manner the distance from the face of the small mirror to the centre division of the telescope scale was found to be $9\frac{503}{1000}$ feet, and the length of one minute 0.0663 inches.

For the declinometer the distance from centre of large mirror to position of trace on the cylinder was $9\frac{415}{1000}$ feet, and the length of one minute determined therefrom 0.0657 inches. From the small mirror to telescopic scale the distance was found to be $9\frac{325}{1000}$ feet, and the length of one division 0.0651 inches. The corresponding distances and values of the balanced magnetometer were $9\frac{269}{1000}$ and $9\frac{767}{1000}$ feet, and 0.0647, 0.0681 inches. Scales were constructed upon strong paper to correspond to these determinations. The three telescope scales were fixed upon firm horizontal bars directly over the telescope, and the register scales were reserved for the reading of the photographic traces.

For the reduction of the records of the horizontal and vertical force magnets, as the angular motion depends not only upon variations of the earth's magnetic force, but also upon the magnetic moments of the magnets, it becomes necessary to determine the constant coefficient for the reduction for each instrument. For the horizontal force magnet the constant is determined by the expression,

$$\frac{\Delta\ F}{F} = \text{cot. } V. \ \Delta\ V.$$

V being the angle of torsion, and Δ V denoting the variations of V in terms of radius.

For the vertical force magnet this coefficient is determined by the expression,

$$\frac{\Delta\ V}{V} = \frac{Th}{Tv} \text{ cot. dip} \times \frac{\text{space on paper,}}{2\ D}$$

in which V represents the vertical force, Th the time of vibration of the magnet in a horizontal plane, Tv the time of vibration in a vertical plane, the vibration being made in each case with the magnet and its attachments complete, so that the moment of inertia shall be the same. Detailed observations for obtaining these coefficients are appended. The vibration of the vertical force magnet in a horizontal plane was made by suspending the magnet by means of a spare suspension skein, six feet in length. This skein was suspended from the ceiling of the room, and the line of detorsion made to coincide with the magnetic meridian by means of a leaden bar. The room was kept closed to avoid currents of air, and the magnet and attachments suspended in a horizontal position by a small wire hook made for the purpose; the magnet was then made to vibrate in a small arc, and the times of vibration noted by observing the passage of a reflected beam from the mirror across a line on the opposite wall. Several hundred vibrations were observed, and the time noted by a chronometer. The vibrations in a vertical plane were made with the magnet in its position on the knife edges, the time being observed by noting the passage of a certain division across the horizontal wire of the telescope.

The angular value of the telescope scale of the vertical force magnet requires a correction for the obliquity of the small mirror to the axis of rotation. This mirror could not be placed with its plane parallel to the axis of rotation, and consequently the angular motion of the mirror is less than the angular motion of the magnet, in the proportion of unity to the cosine of the inclination. The inclination was measured very carefully by stretching a fine thread in the direction of the axis of motion, and a second in the direction of the face of the mirror, across the box enclosing the magnet, thus forming a right-angle triangle with the threads and a part of one side of the box.

The base of the triangle was $12\frac{93}{100}$ inches, and the altitude $0.\frac{99}{100}$ inch, from which the angle at the base was determined.

Another mode for determining the value of the scale of the bifilar magnet in terms of the

horizontal force given by Mr. Brooke was also employed. This method consists in placing small auxiliary weights upon the magnet frame, and observing the angular change of the magnet by the scale, the auxiliary weights having a given proportion to the whole weight of the magnet and its attachments; by observing the difference of the angle of torsion with the weights on and off, the value of one division may be determined. The observations by this method will be found with the results of the other experiments.

Experiments for determining the temperature coefficients of the horizontal force and vertical force magnets.

The automatic compensation for temperature not having been adopted for these magnets, and the temperature coefficients not having been obtained since the determination of Mr. Brooke, nearly ten years since, it became necessary to redetermine these constants by experiments before the instruments were finally set up for observations. For this purpose the method of Lamont was employed; the apparatus consisting of a magnetometer of the construction devised by Gauss, to which bars were attached for supporting the magnets. The bars were supported by braces attached to an upright piece resting upon the upper plate of the magnetometer; the whole forming a sort of truss, light but strong.

The truss turned with the upper plate. A small magnet was suspended in the magnet-stirrup by the bifilar suspension, and brought to coincide with the magnetic meridian, the wire of the telescope coinciding with a certain division. A zinc box containing the magnet was then placed upon one of the bars, and hot and cold water alternately poured into the box, care being taken not to disturb the magnet or the instrument. The wire of the telescope was kept on the same division by turning the upper plate, bars and all, and the readings of each taken when the magnet had attained a steady temperature, the circle reading to ten seconds. The temperature of the magnet was recorded during the observations by a thermometer placed within the box. Readings of the declinometer were then taken during the experiments; but there being no means of observing the change of magnetic force during their progress, the results are to be combined so as to eliminate any error from this cause.

Photographic arrangements.

The photographic process for recording the variations of the magnets is, of course, one of the most prominent features of an observatory of this character. As before explained, the light from the lamps is reflected from the mirrors attached to the suspended magnets, and falls upon the surface of the cylinders around which the paper, rendered sensitive by the application of iodide of silver, is wrapped; and the cylinder making one revolution in 24 hours, the variations of the magnet are traced by the action of the light in a curve upon the paper. The central cylinder produces two traces—one for the declinometer, near one end of the cylinder, and the other for the horizontal force magnet, on the other end, and on the opposite side.

The trace of the vertical force magnet is made on a separate cylinder, as before described. This arrangement requires the use of two prepared sheets each day—one thirteen inches wide and over two feet in length, and the other half the width and the same length. There are thus used 730 sheets in a year, each of which must be prepared by a separate process, both to render it sensitive before it is put on the cylinder, and to bring out and fix the trace after it has been taken off. For the convenience of preparing these sheets, and storing the necessary chemicals and paper, a separate room of liberal dimensions is required. This room should be clean and close, so as to be free from dust, with shelves for containing the chemicals and tables for operating. To provide such a room, the main interior building was extended ten feet beyond the dimensions required for the instruments, and a partition thrown across ten feet from the end; the space cut off was then furnished with shelves and tables for the purposes

required—one door leading from this room to the instrument room, and another to the exterior anteroom.

The whole room under the shed not being occupied, a large anteroom was left for the storage of boxes and for a general working and computing room. The only expense bestowed upon this part of the building was the cost of a rough floor.

The operating room was provided also with a water sink and cock for drawing water from a large cask placed at the extreme end of the anteroom. The various chemicals and photographic materials required were obtained in New York. The chemicals required are principally nitrate of silver, iodide of potassium, hyposulphite of soda, and gallic acid, small quantities of various other chemicals being also provided; the various implements for the photographic process, such as glass jars, funnels, glass rods, glass tubes, brushes, demijohns for pure water, filtering paper, blotting paper, and towels, completing the necessary furniture of the room. The room was provided with two windows, covered with yellow envelope paper to prevent the entrance of white light during the preparation of the paper.

The windows were first stained with a yellow varnish, but this did not seem to afford sufficient obstruction to the actinic rays, and they were then covered with paper.

The photographic process for rendering the paper sensitive is quite simple, but considerable skill and care in manipulation are required to produce a clear sheet, having the trace brought out clearly and well defined. This can only be secured by practice and experience. The process employed varies somewhat with different manipulators; the principal operations being the same with all: these are to saturate the surface first with a solution of iodide of potassium, then with a solution of nitrate of silver. The free nitrate is then rinsed off with pure water and the paper dried in a dark place; when dry it may be kept for several days and even weeks before being used. When required for use it is put on the cylinder, and after having received the impressions of the light from the lamps during one revolution, it is taken off and a weak solution of gallic acid, to which a few drops of nitrate of silver are added, is brushed over the surface of the paper, which brings out the trace. As soon as the trace is distinct the action of the acid is checked and the trace fixed by immersing the paper in a solution of hyposulphite of soda. After having remained a sufficient length of time under the influence of the hyphosphite, it is placed in a swimming dish filled with pure water, where the surplus chemicals are dissolved and from which it is taken and dried. Some prefer to saturate the paper with the various chemicals by swimming, others by the use of broad hair brushes, and again others by what is known as Buckel's brush, a small bundle of fancy cotton held by a silver wire and a glass tube. Much depends upon personal skill and experience, the purity of the chemicals, and the cleanliness of the vessels and implements.

Mr. Samuel Walker having brought this process to great perfection in his experience at Key West, under my direction, and afterwards while in charge of the observatory, I will here give the details of his process in his own words:

"Having to-day, May 25, 1860, given up the photographic self-registering observations to Mr. Allen, to be continued by him, I subjoin a brief account of the mode of preparation of the paper furnished by Mr. Hilgard, of which there is on hand more than three years supply. This paper proves to be good, as the last photographic sheets prepared from it will show. It has been used successfully since May 7.

"1. Immerse the sheet until thoroughly saturated in a solution of 240 grains of iodide of potassium, in ten ounces of pure water obtained from melted ice, and well filtered. Hang it up in the open air and light of the ante-room till dry.

"2. In a dark room, the light of a common candle being used, float it on a solution of 320 grains of nitrate of silver in 10 ounces of water (same kind as used for the I. P.) for one minute and fifteen seconds; hold it by the corner to drip for one minute and thirty seconds. At the expiration of this time, $2\frac{3}{4}$ minutes from the time of first touching the surface of the N. S., the

action of the N. S. on the I. P. contained in the paper is complete, and it is then instantly washed in at least six changes of common cistern water for three minutes in all. The more water used and the more frequently it is changed the better, provided the total time of washing does not exceed three minutes. Washing under a running spout where there is a fresh supply of water continually passing over the paper is the best. This removes the free N. S. and prevents the blackening of the sheet in bringing out the trace. The paper is then hung up to dry in the dark, and carefully kept from all light except that intended to produce the trace, until the trace is finally fixed by the H. S. solution. Paper thus prepared will keep for any length of time before using. It is put on the cylinder dry. To bring out the trace a saturated solution of gallic acid (in pure water from melted ice) is used, with the addition of a few drops of the N. S. solution at the time of using. This solution is spread on the sheet with a cotton brush.

"To fix the trace and destroy the iodide of silver, which has not been affected by the light, the sheet, after washing in several changes of water, is immediately immersed in a solution of one ounce of hyposuphite of soda in 10 ounces of common cistern water, from 10 to 15 minutes. It is then washed again in several changes of water and soaked for 24 hours in 3 changes of water. Dry it by laying it flat on a smooth pine board."

By following strictly the above process in all its details, Mr. Walker succeeded in obtaining traces as distinct and well defined as could be desired, while the main ground was in no way disfigured by dark spots.

For obtaining pure water the cistern water of Key West was first tried, but failed on account of the existence of animal matter in it, which produced a black curdy solution with nitrate of silver when exposed for some time to the light.

Water obtained by melting ice was found to be almost entirely free from impurities, and answered well the required purposes.

The quantity of chemicals required for a given period will be determined during the year.

The daily duties of the observer are generally as follows: to make the necessary meteorological observations at the required periods; to prepare the paper for one day or for several days in advance. At a stated time in the day, when the magnets are most nearly stationary, he takes a prepared sheet and places it upon one of the cylinders, there being one extra cylinder to each instrument. The sheet is fastened to the cylinder with thumb tacks or gum. He then goes to the instrument room and reads the telescope scale of the instrument, and records the reading in a hand-book, notes the time by the clock in his book, marks the point of the trace corresponding to this time with a pencil, and the name of the instrument, date, &c. The cylinder is then taken off without stopping the clock, and the extra one put in its place, with a new sheet. The time of commencement is marked on the sheet, and in his book, the scales read, and the cylinder put in motion. The cylinder covers being placed on to protect the paper from dust. This done for each instrument, he fills the lamps and then developes the traces taken off, and finishes by leaving the traces swimming in the hyposulphite of soda.

His time is then occupied in drying the sheets of the day before, and in reading, by means of a scale, the registers of those which are dry, and preparing his records for transmission to the office.

The results of the first twenty days observations at Key West are given in the duplicate volume of records herewith transmitted.

Absolute determinations of the Magnetic Elements.

The absolute values of the magnetic elements are determined, in connection with the differential observations, by a separate set of instruments provided for the purpose, and mounted in a small building erected for their reception, about seventy-five yards north of the principal observatory.

The building is eight feet five inches × six feet five inches, and seven feet high to the pitch of the roof; it rests upon stone supports, a central stone pier serving to support the instruments in use.

The instruments are a theodolite magnetometer for determining the absolute declination and horizontal intensity, and a dip circle of large dimensions for observations of the dip.

Openings, closed by sliding-doors in the roof and sides, admit of observations on the north star, and on the NW. and Key West light-houses. The northwest light, distant several miles, furnishes a good azimuth mark, the bearing of which was well determined. The theodolite of the magnetometer furnishes the means of determining the time. The instruments when mounted being protected from the weather they may be kept in place for any desired interval of time, and observations taken in conjunction with scale-readings of the fixed instruments. The building and pier were put up under my direction, and the observations then conducted by Mr. Samuel Walker.

The following results were obtained previous to my departure from Key West.

Axis of magnet H. 20th div.

Date.	Reading of meridian.	Reading of app. mer.	App. mag. mer. E. of true mer.	Mean scale readings.	Red. to zero.		Declination E. of N. N.
					Divs	Arc.	
	° ′ ″	° ′ ″	° ′ ″				° ′ ″
February 16, 1860	43 29 6	48 34 7	5 05 1	16.1	3.9	—8.5	4 56 6
February 17, 1860	43 29 6	48 34 7	5 05 1	17.6	2.4	—5.2	59 9
	Brick pier remov	ed and stone pier	put up.				
	Mean declination	of Feb. 16 and 1	7				= 4 58 3
March 17, 1860	45 16 4	50 03 6	4 47 2	18.6	1.4	—3.0	4 44 2

A discrepancy occurs in the observations of March 17 which cannot be due to the azimuths, as they agree; it can only be explained by subsequent results. It may be due to the effect of the change of the pier from brick to stone.

Recapitulation of results for horizontal intensity and magnetic measurement of magnet H.

Date.	Set.	X.	M.
February 15, 1860	1.	6.7335	0.8378
Do	2.	6.7250	0.8367
March 13, 1860	1.	6.7590	0.8385
Do	2.	6.7510	0.8375
March 21, 1860	1.	6.7610	0.8365
Do	2.	6.7662	0.8371
Do	1.	6.7507	0.8366
Do	2.	6.7490	0.8364
Mean		6.7494	0.8371

Log. X = 0.82926
Dip = 54° 39′ 00″ sec. 0.23764

1.06690

Total intensity = 11,665

RECAPITULATION OF OBSERVATIONS FOR DIP.

FEBRUARY 18, 1860.

Needle No. 1.		Needle No. 2.
54° 41′ 6″.		54° 43′ 0″.

Resulting dip, 54° 42′ 3″.

MARCH 12, 1860.

Needle No. 1.		Needle No. 2.
54° 36′ 2″.		54° 39′ 3″.

Resulting dip, 54° 37′ 8″.

MARCH 21, 1860.

Needle No. 1.		Needle No. 2.
54° 35′ 4″.		54° 38′ 5″.

Resulting dip, 54° 37′ 0″.

Mean resulting dip, 54° 39′ 00″.

The observations and computations of these results are given in the volume of records herewith transmitted. The observations with the portable instruments were made by Mr. Samuel Walker, who assisted me also in putting up the other instruments, and whose skill and intelligence during the whole work are especially commendable. Mr. Walker has had sole charge of the magnetic station since March 2.

The services of Mr. G. D. Allen were engaged for the summer months, and if necessary continuously, as observer, in place of Mr. Walker, when the condition of the climate should render it necessary for the latter to leave Key West. Mr. Allen was instructed thoroughly in the use of the instruments, and from his skill and knowledge, accompanied with a zealous interest in the success of the observations, will, I think, prove a valuable observer for this station.

I desire to express my warmest acknowledgments for the assistance rendered to me and to the survey, during the progress of my labors at Key West, by Capt. E. B. Hunt, Corps of Engineers, and Mr. James Clapp.

Diagrams illustrating the plan of the observatory and the mode of mounting the fixed instruments are given in Sketch No. 23.

Diagram No. 1 represents the plan of the observatory, the relative positions of the piers, and the general arrangements of the operating room.

Diagram No. 2 represents the mode of mounting the declinometer and horizontal force magnets, and the recording cylinder and clock for both.

Diagram No. 3 represents the mode of mounting the vertical force magnet, and its clock and cylinder.

SCALE VALUES FOR REGISTERS OF HORIZONTAL AND VERTICAL FORCE MAGNETS.

Determination of scale value of register of horizontal force magnet.

Angle of torsion				= 35° 07′
Cotangent	35° 07′	log	0.15289	
Sine	1″		6.46373	
Scale value			6.61662	K = 0.0004136

SCALE VALUE OF VERTICAL FORCE MAGNET.

Feb. 24.—Vibrations of vertical force magnet in a vertical plane.

No. of vibrations.	Time.			Time.			Time.			No. of vibrations.	Time.		
	h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*
0	4	41	06.0	4	44	53.0	4	48	49.0	0	4	55	22.0
2			21.5		45	07.5		49	03.5	2			37.0
4			36.5			23.0			18.0	4			57.5
6			51.5			37.5			32.5	6		56	06.5
8		42	07.0			52.5			47.0	42	5	00	27.5
10			22.0		46	07.0		50	01.5				
12			37.0			22.0			15.5				
14			52.0			36.5			30.0				
16		43	07.0			51.0	4	50	44.5				
18			22.0		47	05.5							
20			37.0			20.0							
22	4	43	51.5	4	47	34.5							

Feb. 24.—Vibrations of vertical force magnet in a vertical plane.

No. of vibrations.	Time.			No. of vibrations.	Time.			Remarks.
	h.	*m.*	*s.*		*h.*	*m.*	*s.*	
0	5	02	14.0	0	5	29	33.0	These are different sets of vibrations. Mean time of one vibration, 14*s*.33. Mean time of double vibration in a vertical plane .... 14*s*.464 Single vibration .... 7*s*.232 Vibration observed by the instant a certain division of scale passed the vertical wire of the telescope.
16		06	00.5	20		31	56.0	
				40		34	18.0	
0	5	08	11.5					
40	5	13	00.0	0	5	39	02.5	
				20		41	27.5	
				40		43	51.0	
0	5	20	30.5					
60	5	27	40.5					
				0	5	46	16.0	
0	5	55	59.0	20		48	....	
40	6	00	44.5	59		53	16.0	

Feb. 24.—Vibration of vertical force magnet in a horizontal plane.

No. of vibrations.	Time. h.	m.	s.		Remarks.
0	9	20	38.0		Magnet suspended by a bundle of silk fibres six feet in length; torsion first taken out by suspending a bar of lead in place of magnet. Magnet suspended with all the attachments it had in the vertical vibration.
2			56.0		
4	9	21	14.3		
6			32.5		
8			50.7		
10	9	22	09.0		
12			27.0		The room in which it was suspended was closed, so that no current of air could affect it.
14			45.5		
16	9	23	03.5	60 vib.	Vibration observed by the instant a reflection from a candle from the mirror passed a certain point on the opposite wall.
	9	41	14.5	40 vib.	
	9	53	22.0	10 vib.	
	9	56	23.7	30 vib.	Mean time of single vibration = 9s.090.
	10	05	28.5		

Computation.

$$\frac{\Delta v}{v} = \frac{\mathrm{Th}^2}{\mathrm{T}v^2} \text{ Cot. dip} \times \text{value of one division in terms of radius.}$$

Th = 9s.090	log	0.95856
Tv = 7s.232	log	0.85926
		0.09930
$\frac{\mathrm{Th}^2}{\mathrm{Tv}^2}$	log =	0.19860
Dip = 54° 39′ cot	log =	9.85086
Sin. 1′		6.46373
$\frac{\Delta v}{v}$		6.51319

$$\frac{\Delta v}{v} = \quad 0.000326$$

Observations February 21.—Experiments for determining the temperature co-efficient of the horizontal force magnet by Lamont's method.

[Distance between centers = 2 feet + 6.5 inches.]

Temp. of air.	Time, p. m.	Circle readings. A.	Circle readings. B.	Circle readings. C.	Fixed declinometer div.	Temp. of deflecting magnet.	N. end E. and W.	Magnet E. and W.
°	h. m.	° ′ ″	° ′ ″	° ′ ″		°		
	3 31	....	....	....	47.			
	3 39	133 00 00	....	....	47.5			
	3 43	133 18 40	18 50	....	....	115. F.	E.	E.
79	3 54	125 32 00	32 10	....	47 0	112.5	W.	E.
	4 03	133 20 20	20 35	....	47.1	111.0	E.	E.
79	4 14	125 32 30	32 40	....	48.0	109.5	W.	E.
	4 21	133 22 10	21 30	....		108 5	E.	E.
	4 39	125 32 20	31 30	....	47.1	106.0	W.	E.
			ICE WATER PUT IN.					
75	5 00	125 18 30	....	245 18 00	47.0	43.5	W.	E.
75	5 21	133 34 40	....	253 34 20	49.	43.7	E.	
	5 27	125 21 10	....	20 50	50.	44.	W.	
75	5 33	133 40 40	....	253 40 00	53.	44.	E.	
	5 44	125 25 50	....	25 10		45.	W.	
75½	5 53	133 39 00	....	253 38 20	52.6	46.	E.	
			ICE WATER PUT IN.					
75½	8 17	133 39 10	....	253 39 00	52.0	39.5	E.	
		39 20	....	39 20	....	....	E.	
		39 40	....	39 50	....	....	E.	
76	8 27	40 10	....	40 20	53.3	39.5	E.	
			HOT WATER PUT IN.					
75½	8 50	133 27 00	....	253 27 20	53.6	99.5	E.	
		27 30	....	27 30	54.0	98.5	E.	
		29 30	....	29 30	53.7	98.	E.	
76	9 7	29 20	....	29 20	53.5	97.	E.	
77	....	133 38 30	....	253 38 20	52.8	47.	E.	E.
		38 40	....	38 30	....	....	E.	E.
		38 30	....	38 20	....	....	E.	E.
77	9 39	38 40	....	38 20	52.5	47.5	E.	E.
			HOT WATER PUT IN.					
76.8	9 57	133 27 20	....	253 27 00	52.8	98.	E.	
		28 00	....	27 30	....	....	E.	
		28 20	....	27 40	....	....	E.	
77	10 07	28 20	....	27 50	53.	97.	E.	
	10 20	129 27 00	....	249 26 50	....	....	....	Magnet removed.
		27 00	....	26 50				
	10 25	27 00	....	27 00	53.			
		27 10	....	27 00				

Experiments for determining the temperature coefficient of the horizontal force magnet—Continued.

[Distance between centres = 2 feet + 6.5 inches.]

FEBRUARY 22, A. M., AT 9*h*. 8*m*. PUT IN HOT WATER.

Temp. of air.	Time, p. m.	Circle readings. A.	Circle readings. B.	Circle readings. C.	Fixed declinometer div.	Temp. of deflecting magnet.	N. end E. and W.	Magnet E. and W.
°	*h. m.*	° ′ ″	° ′ ″	° ′ ″		°		
77	9 31	125 29 50	....	29 40	54.8	108.	W.	W.
		29 40	....	29 50				
		29 40	....	29 40				
77.8	9 50	29 00	....	28 50	54.5	105.		

ICE WATER PUT IN.

77	10 26	125 11 30	....	11 30	53.0	39.8	W.	W.
		11 30	....	11 40				
		11 20	....	11 10				
77	10 35	10 50	....	10 50	52.2	41.		
	10 46	129 26 40	....	26 50	52.	....	......	Magnet removed.
		26 30	....	26 20				
		26 50	....	26 30				
	10 56	26 30	....	26 30	51.6			

N. end east and magnet E. deflects N. end of small magnet east.

Horizontal force magnet C. B. X. Determination of the change of magnetic moment for 1° *of temp. First set. February* 21, 1860.

	Time.	North end.	Mean circle reading.	Mean fixed dec. reading.	Diff.	Corrected circle reading.	2 *u*.	*u*.	Mean temp.
	h.		° ′ ″	′	′ ″	° ′ ″	° ′ ″	° ′ ″	°
Hot	4.0	E.	133 20 21	47.3		133 20 21	7 48 09	3 54 04	110.4
		W.........	125 32 12	47.3	0 00	125 32 12			
Cold	5.5	E.	133 37 50	51.5	− 4 12	133 33 38	8 14 39	4 07 19	44.4
		W.........	125 21 35	49.9	− 2 36	125 18 59			
								13 15	66.0

Mean $u = 4°\ 00'\ 42''$ — $13'.25$ log. 1.12222

$u_o - u_h = 13'.25$ — Sin 1′ log. 6.46373

$t_h - t_o = 66°$ — Cot u log. 1.15408

66° co log. 8.18046

$0.000833 = q$ — log. 6.92049

Second series, February 21, 1860.

	Time.	Mean circle reading.	Mean fixed dec. reading.	Diff.	Corrected circle reading.	Diff., or $u - u$	Mean temp.	Diff, or $t_h - t_o$
	h.	° ′ ″	′ ″	′ ″	° ′ ″	′ ″	°	°
Cold.............	8.4	133 39 36	52 39	....	133 39 36	12 17	39.50	58.75
Hot.............	9.0	133 28 22	53 42	—1 03	27 19		98.25	
Cold.............	9.6	133 38 30	52 39	0 00	38 30	11 11	47.25	51.00
Hot.............	10.0	133 27 45	52 54	—0 15	27 30	11 00	97.50	50.25
Mean............	....	....	....	....	133 33 14			
Magnet removed..	10.4	129 27 00	53 00	—0 21	129 26 39			
				$u =$	4 06 35			

12′.28	log. 1.08920	11′.18	log. 1.04844	11′.00	log. 1.04139
Sin 1′	log. 6.46373	Sin 1′	log. 6.46373	Sin 1′	log 6.46373
Cot u	log. 1,14358	Cot u	log. 1.14358	Cot u	log. 1.14358
58°.75 co	log. 8.23099	51°.00 co	log. 8.29243	50°.25 co	log. 8.29886
	6.92750		6.94818		6.94756
$q = 0.000846$		$q = 0.000887$		$q = 0.000886$	

Third set, February 22, 1860.

	Time.	Mean circle reading.	Mean fixed dec. reading.	Diff.	Corrected circle reading.	Diff., or $u_h - u_o$	Mean temp.	Diff., or $t_h - t_o$
	h.	° ′ ″	′ ″	′ ″	° ′ ″	′ ″	°	°
Hot.............	9.7	125 29 31	54 39	0 00	125 29 31	16 10	106.5	66.1
Cold.............	10.5	125 11 18	52 36	+2 03	125 13 21		40.4	
Mean............	....	....	....	....	125 21 26			
Magnet removed..	10.8	129 26 35	51 48	+2 51	129 29 26			
				$u =$	4 08 00			

16′.17 log. 1.20817
Sin 1′ log. 6.46373
Cot u log. 1.14107
66.1 co log. 8.17980

0.000983 = q log. 6.99277

First set..	$q = 0.000833$
Second series..	0.000846
Do...	0.000887
Do...	0.000886
Third set..	0.000983
Mean...	$q = 0.000887$

As less weight should be given to the first and third sets, it will be better to use $q = 0.00088$.

Table of corrections for temperature of horizontal force magnet. Record for March, 1860.

$-\frac{q}{2}\left(t_0 - t\right)$ KEY WEST.

Days.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
Hours.	Corrections in scale divisions.										
1	....	—0.2	+5.4	+10.1	+9.6	+16.3	+21.3	+23.4	+21.7	+14.5	+9.6
2	....	—0.4	5.3	10.0	9.0	16.4	21.3	23.4	20.8	14.3	9.1
3	....	—0.8	4.7	9.9	8.4	16.5	21.3	23.4	19.8	14.2	8.5
4	....	—0.8	4.3	9.8	7 8	16.6	21.3	23.4	18.8	14.1	8.0
5	....	—1 0	3.4	9.7	7.4	16 8	21.3	23.4	17.8	13.9	7.5
6	....	—1.2	2.8	9.7	7.0	16.9	21.3	23.4	16.9	13.8	7.0
7	....	—1.5	2.7	9.6	6.4	17.0	21.3	23.4	16 0	13 7	6 4
8	....	—0.2	3.6	10.8	8.1	18.1	22.0	23 8	15.8	13.4	7.1
9	....	+1.0	4.3	12.0	9.8	19.2	22.8	24 1	15.7	13.1	7.8
10	....	2.1	6.0	13.2	11.7	20.3	23.5	24.5	15.5	12.7	8.5
11	....	3.2	7.5	14.4	13.2	21.3	24.2	24.8	15.3	12.4	9.2
12	....	4.9	8.5	15.6	15.0	22.4	25 0	25.1	15.1	12.0	9.9
1	....	6.3	9.6	16.8	15.9	23.5	25.7	25.6	14.9	11.7	10.6
2	....	6.4	9.8	16.2	15.9	23.2	25.4	25.6	14.9	11.7	10.6
3	....	6.5	9 9	15.6	15.9	22.9	25.1	25.6	14.9	11.7	10.6
4	....	6.6	10.0	15.0	15.9	22.6	24.8	25.6	14.9	11.7	10.6
5	....	6 8	10.1	14.4	15.9	22.3	24.5	25.6	14.9	11.7	10.6
6	....	6.8	10.2	13 8	15.9	22.0	24.4	25.6	14.9	11.7	10.6
7	....	7.0	10.4	13.2	15.9	21.8	24.0	25.6	14 9	11.7	10.6
8	....	7.2	10.5	12.8	15.9	21.5	23.7	25.6	14.9	11.7	10.6
9	....	7.4	10.6	12.0	15.9	21.3	23.4	25.6	14.9	11.7	10.6
10	....	6.9	10.5	11.4	16.0	21.3	23.4	24.6	14.8	11.2	....
11	....	6.4	10.4	10.8	16.1	21.3	23.4	23.6	14.7	10.7	....
12	....	5.9	10.2	10.2	16.2	21.3	23.4	22.7	14.6	10.1	....

Diagrams 1 and 2, Sketch No. 24, represent by curves the variations of the declination and horizontal force at Key West, from March 11, 1860, to March 21, 1860.

In diagram No. 2 the variations of temperature are represented by the curve marked *temperature*, and curves are drawn to show the variations of the magnetic force as recorded and reduced from the photographic sheets, and the variations after having been corrected for temperature.

Observations February 22.—*Determination of temperature coefficient of vertical force magnet. Vertical force magnet, C. B. XIII.*

PUT IN ICE AT 11*h.* 7*m.*

Temp. of air.	Time, a. m.	Circle readings. A.	Circle readings. B.	Circle readings. C.	Fixed declinometer div.	Temp. of deflecting magnet.	N. end E. and W.	Magnet E. and W.
°	*h. m.*	° ′ ″	° ′ ″	° ′ ″	′	°		
79	11 22	122 14 10	....	14 20	52.2	40.3	W.	W.
		14 10	....	14 20				
		14 10	....	14 10				
78.8	11 32	14 20	....	14 00	51.9	40.0		

PUT IN HOT WATER AT 11*h.* 47*m.*

	P. M.							
80	12 3	122 17 10	....	17 00	51.0	114.0	W.	W.
		17 00	....	16 50				
		16 30	....	16 20				
80	12 14	16 30	....	16 30	50.7	111.0		

Observations February 22.—Determination of temperature coefficient of vertical force magnet—Continued.

PUT IN ICE AT 12*h*. 24*m*.

Temp. of air.	Time, p. m.	Circle readings. A.	Circle readings. B.	Circle readings. C.	Fixed declinometer div.	Temp. of deflecting magnet.	N. end E. and W.	Magnet E. and W.
°	*h. m.*	° ′ ″	° ′ ″	° ′ ″	′	°		
80	12 38	122 12 00	....	12 10	50.0	36.5	W.	W.
		12 20	....	12 20				
		12 30	....	12 20				
80.2	12 47	12 20	....	12 20	49.3	36.5		

PUT IN HOT WATER AT 1*h*. 05*m*.

Temp. of air.	Time, p. m.	A.	B.	C.	Fixed declinometer div.	Temp. of deflecting magnet.	N. end E. and W.	Magnet E. and W.
80	1 18	122 16 30	....	16 20	49.0	115.5	W.	W.
		16 00	....	16 00				
		15 50	....	16 00				
	1 25	16 00	....	15 50	49.1	114.0		
	1 31	129 21 10	....	21 00	49.0	....	......	Magnet removed.
		20 50	....	20 30	49.0			
	1 40	20 40	....	20 30	49.0			
		20 30	....	20 20				
80	1 45	....	....	....	50.0	110.0		
80	3 05	136 19 30	....	19 30	50.0	105.0	E.	W.
		19 20	....	19 00				
		19 50	....	19 40				
80	3 17	16 50	....	19 50	49.9	103.0		

ICE PUT IN.

Temp. of air.	Time, p. m.	A.	B.	C.	Fixed declinometer div.	Temp. of deflecting magnet.	N. end E. and W.	Magnet E. and W.
80	3 37	136 23 20	....	23 20	50.0	35.0	E.	W.
		23 20	....	23 10				
		23 30	....	23 20				
79.5	3 45	23 40	....	23 30	50.5	35.5		

HOT WATER PUT IN.

Temp. of air.	Time, p. m.	A.	B.	C.	Fixed declinometer div.	Temp. of deflecting magnet.	N. end E. and W.	Magnet E. and W.
79.2	3 59	136 20 10	....	19 50	50.7	112.0	E.	W.
		20 20	....	20 00				
		20 10	....	19 40				
79.2	4 07	19 50	....	19 40	51.0	111.0		

PUT IN ICE.

Temp. of air.	Time, p. m.	A.	B.	C.	Fixed declinometer div.	Temp. of deflecting magnet.	N. end E. and W.	Magnet E. and W.
79.2	4 21	136 24 00	....	23 50	51.0	38.0	E.	W.
		23 50	....	23 40				
		23 40	....	23 30				
79.5	4 33	23 40	....	23 30	50.5	39.0		
	4 40	129 24 40	....	24 20	50.7	....	.....	Magnet removed.
		24 20	....	24 00				
		24 40	....	24 30				
	4 49	25 00	....	24 40	51.1			

Vertical force magnet, C. B. XIII.—Determination of the change of magnetic moment for 1° of temperature. First series. Feb. 22, 1860.

	Time.	Mean circle reading.	Mean fixed dec. reading.	Diff.	Corrected circle reading	Diff., or $v_h - v_o$	Mean temp.	Diff., or $t_h - t_o$
	h.	° ′ ″	′ ″	′ ″	° ′ ″	′ ″	°	°
Cold	11.4	122 14 13	52 03	....	122 14 13	3 43	40.15	72.35
Hot	12.1	122 16 44	50 51	+ 1 12	122 17 56	3 14	112.50	76.00
Cold	12.7	122 12 18	49 39	+ 2 24	122 14 42	4 22	36.50	78.25
Hot	1.4	122 16 04	49 03	+ 3 00	122 19 04		114.75	
Mean	....	....	....	....	122 16 29			
Magnet removed	1.6	129 20 42	49 00	+ 3 03	129 23 45			
				u =	7 07 16			

The change of magnetic movement for 1°, viz: q, is found from the formulæ—

$$q = \frac{(v_h - u_o) \sin 1' \cot u}{t_h - t_o}$$

3′.72	log. 0.57054	3′.23	log. 0.50920	4′.37	log. 0.64048
Sin 1′	log. 6.46373	Sin 1′	log. 6.46373	Sin 1′	log. 6.46373
Cot u	log. 0.90334	Cot u	log. 0.90334	Cot u	log. 0.90334
72°.35 arco	log. 8.14056	76°.00 co	log. 8.11919	78°.25 co	log. 8.10652
q	log. 6.07817	q	log. 5.99546	q	log. 6.11407
q = 0.0001197		q = 0.0000990		q = 0.0001300	

Vertical force magnet, C. B. XIII. Second series. Feb, 22, 1860.

	Time.	Mean circle reading.	Mean fixed dec. reading	Diff.	Corrected circle reading.	Diff., or $u - u$	Mean temp.	Diff., or $t_h - t_o$
	h.	° ′ ″	′ ″	′ ″	° ′ ″	′ ″	°	°
Hot	3.2	136 19 34	49 57	....	136 19 34	3 32	104.00	68.75
Cold	3.7	136 23 24	50 15	− 0 18	136 23 06	4 02	35.25	76.25
Hot	4.0	136 19 58	50 51	− 0 54	136 19 04	3 51	111.56	73.00
Cold	4.4	136 23 43	50 45	− 0 48	136 22 55		38.50	
Mean	....	....	....	....	136 21 10			
Magnet removed	4.7	129 24 31	50 54	− 0 57	129 23 34			
				u =	6 57 36			

3′.53	log. 0.54777	4′.03	log. 0.60531	3′.85	log. 0.58546
Sin 1′	log. 6.46373	Sin 1′	log. 6.46373	Sin 1′	log. 6.46373
Cot u	log. 0.91337	Cot u	log. 0.91337	Cot u	log. 0.91337
68°.75 co	log. 8.16273	76°.25 co	log. 8.11776	73°.00 co	log. 8.13668
q	6.08760	q ....log.	6 10017	q ....log.	6.09924
q = 0.0001223		q = 0.0001259		q = 0.0001257	

First series .... q =	0.0001197	0.0001162
Do........................	0.0000990	
Do........................	0.0001300	
Second series........................	0.0001223	0.0001246
Do........................	0.0001259	
Do........................	0.0001257	
Mean........................ q =	0.00012	

APPENDIX No. 27.

Description of the magnetic station at Eastport, Maine, by Assistant L. F. Pourtales.

COAST SURVEY OFFICE, *October* 23, 1860.

DEAR SIR: In compliance with your instructions, I visited the magnetic station at Eastport, Maine, and have the honor to present now the following description of it.

The site of the station was selected by Assistant Geo. W. Dean in the fall of 1859, and a small wooden structure was erected by him on the spot.

It is situated nearly in the centre of the parade ground of Fort Sullivan, in the town of Eastport. The formation on which the fort stands is trap, mostly covered with a thin layer of earth and grass, but the surface is bare in many places. It is a part of uneven plateau extending over the island, which here falls off quite steeply to the east and south. The parade ground is surrounded on the west, north, and east by buildings, all of wood, except a magazine, which is built of stone. On the south a clear view is afforded over the towns of Eastport and Lubeck, the harbor, and Campobello island and Grand Manan. The height is about one hundred and twenty feet above mean low water. A plan of the fort, showing the exact position of the magnetic station has been deposited in the archives.

In December, 1859, Mr. G. B. Vose, who had been assigned to take charge of the station, (and at the same of a self-registering tide-gauge,) proceeded to Eastport with the instruments, consisting of a magnetometer, theodolite, dip circle, chronometer, sextant and artificial horizon, self-registering tide-gauge, and a set of meteorological instruments.

The little structure put up by Mr. Dean was found too small to hold at the same time the magnetometer and dip circle; it was, therefore, enlarged by Mr. Vose, and is now eighteen feet long from east to west, with a breadth of ten feet from north to south. The dip circle stands in the NW. corner, and the magnetometer in the SE. corner, the distance of the instruments from each other being 14 feet $6\frac{1}{2}$ inches from centre to centre. Windows admit the light to each of the instruments, and the building is entered by a door on the west side. The material used in the construction is one-inch pine boards, and the roof and sides are shingled. Of course no iron is used in any part, all the fastenings and nails being copper or zinc.

The steeple of the most elevated church in Lubeck serves as a meridian mark, it is about three and a quarter miles distant, and bears 31′.8 east of south, as was found by observations of Polaris, near elongation. At first Mr. Vose used the flag-staff on Campobello island, and afterwards a flag-staff at Lubeck, for a mark, but both are inconvenient.

The latitude and longitude of the station have not yet been accurately determined.

The magnetometer was constructed in Washington by Mr. W. Würdemann. The magnet box and suspension tube are made in the form usual for portable instruments, and placed over the centre of the azimuth circle. The telescope is supported on inclined pillars connected with the alidade. The circle is six inches in diameter, and reads to thirty seconds by two verniers. The collimator magnet A is $3\frac{3}{8}$ inches long, and $\frac{5}{16}$ of an inch in diameter, and light enough to be suspended by a single fibre. The scale is divided on the glass at the north end of the magnet. This magnet not working satisfactorily it was replaced in October, 1860, by another of the same dimensions. Magnet B, used in the deflection experiments, is $2\frac{7}{16}$ of an inch in length, and $\frac{5}{16}$ of an inch in diameter. The deflecting bars are on Lamont's system.

The dip circle is by the same maker. The circle is $5\frac{1}{2}$ inches in diameter, and supported on columns outside of the glazed box. It reads to thirty seconds by two verniers, and carries two microscopes which are pointed at two small holes in the needle. The azimuth circle reads to minutes, and is also $5\frac{1}{2}$ inches in diameter. The needles, numbered 1, 3, and 4, are $9\frac{1}{2}$ inches in length, and the reading points are $7\frac{1}{2}$ inches apart.

The routine of the work is to make observations on four days in every month, generally the fourteenth, fifteenth, sixteenth, and seventeenth. Observations of declination are made half hourly, from six o'clock a. m. to three p. m., or until the diurnal motion of the needle has become retrograde. In the intervals observations for dip are made with two needles, four sets with each, in two of which the poles are reversed.

After three o'clock observations for horizontal intensity are made, first by deflections, the magnet A being used to deflect magnet B suspended, and afterwards by vibrations, the time of two hundred of which is recorded.

From time to time the vibrations are made with the inertia ring on the magnet to determine the moment of inertia. The torsion is always observed before and after the vibrations.

The magnet A being found to change its magnetic axis, observations for determining the zero of its scale were made before and after the other observations.

Very respectfully, your obedient servant,

L. F. POURTALES,
Assistant U. S. Coast Survey.

Prof. A. D. BACHE, LL.D.,
Superintendent U. S. Coast Survey.

APPENDIX No. 28.

Continuation of the list of magnetic stations and results given in Appendixes No. 28, *Coast Survey Report of* 1856, *and No.* 24, *Coast Survey Report of* 1858.

Number.	Name of station.	Latitude.	Longitude west of Greenwich.	Declination west.	Dip.	Horizontal intensity, English units.	Date.	Locality, geology, and remarks.
		° ′	° ′	° ′	° ′		1859.	
186	Chamcook, New Brunswick..	45 07.5	67 04.6	17 35.7	76 09.4	3.232	Oct. 13–20	Station near the edge of the wood, east side of St. Andrew's road, about half a mile from the geodetic station, on the summit of Chamcook mountain. The formation in the vicinity of the station is chiefly loam; the summit is a dark colored trap rock; on the east side of the mountain there is metamorphic sandstone.
187	Howard, Me.................	44 37.7	67 23.4	18 31.6	75 36.1	3.454	Aug. 9–13	The magnetic station is about 250 metres in a southwesterly direction from the geodetic station. The geological formation is chiefly serpentine rock, with frequent dykes of greenstone trap running in the directions NE. and N.NW.
188	Western Ridge, Me..........	44 59.2	67 27.5	16 31.9	76 20.3	3.175	Sept. 9–15	Station about 49 metres from geodetic station, and in a southwesterly direction from it. The geological formation in the immediate vicinity appears to be felspathic granite, covered with a light soil.
189	Quebec, Canada.............	46 48.4	71 14.5	16 17	77 17.5	2 991	July 18, 19	Station near Wolfe's monument, on the Plains of Abraham, about 300 feet south and east of the monument. The geological formation appears to be black slate.
190	Montreal, Canada	45 30.5	73 34.9	....	76 51.4	3.111	July 20	Station within the enclosure of the McGill University grounds, 36 feet from the southern gate. The geological formation seems to be black slate.
9(*b*)	Bowdoin Hill, Portland, Me..	43 38.8	70 16.2	12 20	....	3.456	July 15	Near the trigonomical station, Bramhall, within the grounds of Mr. J. B. Brown's estate. Drift, coarse gravel. Same station as in 1851.
16(*b*)	Kittery Point, Portsmouth....	43 04.8	70 42.7	11 15	75 04.2	3.496	July 14	Same station as that of August, 1850, east of Mr. Garrishe's cottage. Argillaceous slate.
19(*b*)	Plum Island, Newburyport...	42 48.0	70 48.5	10 58	74 52.9	3.528	July 13	Station near the Plum Island Hotel. Yellowish sand. Same station as that of 1850.
191	Ipswich, Mass..............	42 40.8	70 49.8	11 14	74 37.3	3.598	July 12	This station is about 100 feet south, and a little west of the Congregational church, on a rock 16 feet from the street. Syenite.
20(*b*)	Annis Squam, Cape Ann.....	42 39.4	70 40.3	....	74 56.1	3.589	July 11	At the village pole, hill about 100 feet high. 20 feet south of the flag staff. Syenite rocks; large boulders.

LIST OF MAGNETIC STATIONS—Continued.

Number.	Name of station.	Latitude.	Longitude west of Greenwich.	Declination west.	Dip.	Horizontal intensity, English units.	Date.	Locality, geology, and remarks.
		° ′	° ′	° ′	° ′		1859.	
192	Rockport, Cape Ann	42 39.6	70 36.3	11 37	75 05.9	3.529	July 11	At Allen's Head, west point of Old Garden cove, 130 feet from extreme point of rocks. Syenite.
193	Thompson, Cape Ann........	42 36.7	70 43.5	11 09	74 30.4	3.674	July 9	Primary triangulation station, near Gloucester. Granite.
21 (*b*)	Beacon Hill, Gloucester......	42 36.4	70 38.4	12 03	74 45.6	3.645	July 8	Station on the highest point of the hills, about 185 feet above the sea level, near the station of 1849. The whole region consists of syenite ledges, rocks, and boulders.
194	Rutland, Vt..................	43 36	72 55	9 49	75 19.8	3 464	July 21	In an open lot, near the new post office and bank. Alluvium, limestone, and slate.
195	Deerfield, Mass	42 33	72 36	9 25	74 35.3	3.617	July 23	Station on the public square in the village. Red sandstone with drift overlying.
196	Chesterfield, Mass	42 24	72 51	8 54	74 21.2	3.667	July 25	On a ledge of granite rock west of the three churches, and nearly opposite Taylor's inn.
197	Springfield, Mass	42 06	72 32	8 39	74 14.9	3.691	July 26	Station in an open lot, corner of Chestnut and East Worthington streets.
198	Hartford, Conn	41 46	72 40	....	74 07.4	3 716	July 27	Station in the new park, about halfway between the stone bridge and the bridge leading directly to the railroad depot, about 100 yards from river. Slate and alluvium.
165 (*c*)	Washington, D. C., Coast Survey Office.	38 53.1	77 00.2	....	71 24.4	4.307	June 22, 23, and July 29, 30.	Same station as occupied in 1856. [In Appendix No. 24, 1858, Report, read 1856 for 1858 for this station.]
199	Smithville, Fort Johnson, N.C.	33 55.0	78 00.8	East. 0 38.1	66 17.1	5.230	May 3–5	The station is located within Fort Johnson, and 89.2 metres in a westerly direction from the geodetic station. The soil is chiefly sand.
200	Port Royal, S. C............	32 17.7	80 38.4	3 04.1	64 07.5	....	Jan. 31 to Feb. 5.	At the astronomical station, southwest end of St. Helena island, mouth of Beaufort river.
							1855.	
201*	Mississippi City..............	30 22.9	89 01.0	7 21.8	....	6.178	Mar. 27–30	Identical with astronomical station. It is situated on a ridge of alluvial sea sand; the adjoining country consists of pine barrens, soil being stiff red clay, covered with sea sand.
							1859.	
202	Southeast Pass, Mississippi delta.	29 04.6	89 02.5	....	58 45.3	6.403	Dec. 21	Geodetic station. Soft alluvial soil, blue clay, covered with a thin hard crust when dry; ground very unsteady.
203	Cubitt.......................	29 09.8	89 13.5	7 31.8	58 54	6.375	Dec. 15–16	Near geodetic station. Alluvial soil, blue hard clay, overgrown with short thick grass.
204	Passe à Loutre	29 10.8	89 00.3	7 30	58 47	6.390	Dec. 27	Near mud lump F. Soft alluvial soil, blue clay, very unsteady; covered with thin crust when dry.

APPENDIX No. 29.

Results reported from the observations made by Assistant Charles A. Schott, for magnetic declination, dip and horizontal intensity, on Cape Cod peninsula, Long Island, and the coast of New Jersey.

No.	Locality.	Date.	Latitude.	Longitude.	Declination west.	Dip.	Horizontal intensity.	Total intensity.
		1860.	° ′	° ′	° ′	° ′		
1	Provincetown, Cape Cod	September 14, 15...	42 03.2	70 10.8	11 23.5	74 09.7	3.656	13.396
2	Wellfleet, Cape Cod.......................	September 12, 13...	41 56.1	70 01.5	10 43.5	74 20.2	3.638	13.475
3	Chatham lights, Cape Cod	September 10, 11...	41 40.2	69 56.6	11 11.6	73 46.2	3.744	13.393
4	Sag harbor, Long Island	September 4, 5.....	40 59.9	72 17.1	8 27.7	73 20.9	3.903	13.620
5	Fire island, W. end of base................	September 1, 2.....	40 37.8	73 12.5	7 45.7	73 00.2	3.900	13.341
6	Mount Prospect, Brooklyn.................	September 20, 21, 22	40 40.3	73 57.7	6 44.0	72 40.8	4.052	13.610
7	Barnegat light, N. J......................	August 25, 26......	39 45.8	74 06.0	5 24.0	72 05.3	4.108	13.357
8	Long Beach, N. J.	August 24, 27, 28...	39 32.0	74 15.3	5 18.5	71 58.5	4.156	13.431
9	Absecum light, Atlantic city	August 22, 23......	39 21.8	74 25.0	4 54.0	71 47.0	4.205	13.452
10	Washington, D. C., Coast Survey Office..	Aug. 16, 17, 18, 20, 24; Sept. 25, 26...	38 53.1	77 00.2	2 26.7	71 15.9	4.319	13.446

APPENDIX No. 30.

Extracts from the report of Sub-Assistant F. W. Dorr, descriptive of the coast features near St. Augustine harbor, Fla.

BOSTON, *April* 24, 1860.

SIR :

* * * * * * * * * * * *

The outside beach, both above and below the entrance to St. Augustine, is of sand, backed by a ridge of sand hills from fifteen to thirty feet in height. These sand hills, and, in fact, most of the solid land between them and the inside marsh, are covered with the small scrub-oak and low palmetto, the whole growth being absolutely useless even for firewood.

The shores of the various rivers are mostly marshy, with occasional hammocks of firm land, the whole country, back to the woods, being intersected by a perfect net-work of creeks. The marsh is in most places quite soft, and the creeks often so interlaced as to cut it up into numerous small islands.

St. Augustine is situated on a narrow neck of firm land between the St. Sebastian and Matanzas rivers, and even this is divided in part by a stream called the Maria Sanchez creek.

Anastasia island has much marsh on its western or inside shore, but the middle and eastern portion of the island is composed of alternate ridges and valleys, some of the hills being entirely of sand, others having as their ground work a peculiar conglomerate of shells, lime, and sand, called "Coquina." There are several old quarries in the middle of the island whence this coquina has been taken in the old Spanish times, for it has served as material for nearly all the buildings in St. Augustine, as well as the fort and the sea-wall, which forms the water front of the city. The higher land on Anastasia supports a growth of rather diminutive pines. * * * * * * * * * * *

The outside beach north of the entrance is sandy and remarkably straight, rising from the water into sand hills of various heights, one, the highest on the bank of the Guano river, being nearly fifty feet above the level of the sea. The country between the Guano and north rivers is low and mostly wooded.

The sand hills referred to are in most cases covered with a long stiff grass, which would be sufficient to prevent them from undergoing any serious change of position, except in the event of a succession of very heavy easterly gales.

I think, however, that the sea is encroaching, but so gradually that years must elapse before any change of importance results.

The shoals near the bar and entrance are greatly affected by the winds and tides, and alter perceptibly from one month to another.

Yours, very respectfully,

F. W. DORR,
Sub-Assistant Coast Survey.

Prof. A. D. BACHE,
Superintendent Coast Survey, Washington, D. C.

APPENDIX No. 31.

Remarks on Charlotte harbor, Fla., with sailing directions for entering, and other extracts from the report of Lieut. W. R. Terrill, U. S. A., Assistant Coast Survey, relative to the coast between it and Tampa bay.

GEORGETOWN, D. C., *April* 20, 1860.

DEAR SIR:

* * * * * *

The deepest water at the entrance of Charlotte harbor is close to the shoal making out from the southern point of Gasparilla island, and on it the water breaks in ordinary rough weather.

In the pass, and close to the shore of Gasparilla island, the soundings give ten fathoms, and from the bar to this point the range is from two and a half to ten fathoms. From the pass up to Punta Gorda (near the mouth of Peas creek) vessels can carry two and a half fathoms.

The bar is nearly five miles out from the pass, and shoals up very rapidly. There are two parallel shoals running out and connecting with the bar; one from the southern point of Gasparilla, and the other from the northern point of La Costa island. The general direction of these shoals is southwest and northeast. Inside of the bar, near the pass, and just north of the La Costa shoal, is a second small shoal, with one and a half fathom at the shoalest part. Inside of Boca Grande is the anchorage, and on entering an excellent harbor of refuge will be found for vessels not drawing over twelve feet. A bar and a channel buoy should be placed as guides, and a light near the Coast Survey signal on the southern point of Gasparilla island would enable a vessel to enter at night. At anchor under the lee of Gasparilla or La Costa island vessels would be safe from those destructive westerly gales which sweep the coast.

Sailing directions for entering Charlotte harbor.—Keep in five fathoms water until the Coast Survey signal *or* the southern point of Gasparilla island bears northeast, then steer northeast by east, one quarter east, and cross the bar with two fathoms and a half of water.

* * * * *

That portion of Tampa bay through which I have passed seems to be favorable for triangulation and topography.

Sarasota bay is of the same character as Charlotte harbor from Boca Grande to Bocilla Pass. It is from fifteen to twenty miles long, and from one to four miles broad, and interspersed with numerous small mangrove keys. The depth of water is only about eight feet, and the sand and oyster bars running out from these keys render the channels quite tortuous. The "Pine Bluffs" between Sarasota and Gasparilla present the appearance of a dense forest. The shore is almost a straight line of sand beach. * * *

* * * * *

I am, sir, very respectfully, your obedient servant,

WILLIAM R. TERRILL,
1st Lieut. 4th Artillery, Assistant Coast Survey.

Prof. A. D. BACHE,
Supt. U. S. Coast Survey.

APPENDIX No. 32.

Extracts from the report of Sub-Assistant N. S. Finney, descriptive of the coast and rivers of Florida south of Cedar keys.

BRUNSWICK, GA., *May* 15, 1860.

DEAR SIR:

* * * * *

The principal rivers included within my surveys in this section during the past four seasons are the Waccassassa, the Withlacoochee, the Crystal, the Homosassa, and the

Chassahowitzka. All the anchorages in the bays and near the mouths of these rivers have been carefully noted upon the maps. The channels also leading into the rivers were staked out and traced upon the sheets, and the regular survey has been extended from one to three miles up the rivers. A reconnaissance of the Waccassassa and Withlacoochee rivers was made by Assistant Harrison in 1856. The Crystal river does not extend more than twelve miles into the interior, and heads in a small pond filled with very deep springs. It is properly an arm of the sea, and is brackish throughout. The channel leading into the river is narrow, shallow, and crooked. Vessels drawing five feet can get in at high water, and after getting over the bar find ten feet water to the head of the river. The land on each side is low and marshy, and valuable only for its cedar, large quantities of which are exported to France and England for the manufacture of lead pencils. Some portions of the hammock lands near the coast are very rich, and produce fine cane, corn, and cotton. The forests are filled with a great variety of game and wild animals, as the bear, panther, and deer.

The whole coast from Cedar keys to the Anclote keys, and for ten miles into the interior is a wilderness, with the exception of a few small settlements near the heads of the rivers, and one called Bayport, directly on the Gulf. The Chassahowitzka river is properly an arm of the sea, having low marshy banks, and shallow brackish water. Large quantities of cedar are exported from its vicinity. The Homosassa has a better channel. At high tide vessels drawing six feet can ascend the river to a point three and a half miles from the mouth. It is also an arm of the Gulf, and extends up about six miles from the coast. In character and appearance it is precisely the same as the Crystal river, already noticed.

* * * * *

With respect, your obedient servant,

N. S. FINNEY,
Sub-Assistant Coast Survey.

Prof. A. D. Bache,
Supt. U. S. Coast Survey.

APPENDIX No. 33.

Extracts from the report of Sub-Assistant W. S. Gilbert relative to the topographical features of the shores of San Antonio and Aransas bays, Texas.

Lamar, *Texas*, *August* 8, 1860.

Dear Sir: * * * * The sand mounds on the western side of San Antonio bay are conspicuous from their height, several of them reaching an elevation of sixty feet, and the whole occupying a space of about a square mile, covered by an undergrowth of sweet bay-trees and live-oak, which gives to the locality the appearance of being heavily wooded. The country between San Antonio bay and the head of St. Charles's bay to within three miles of its entrance is sparsely covered by trees, principally live-oak. The scattered "motts" within the same limits afford a refuge for the wild animals that infest the country. Panthers, tiger cats, and mustangs are said to abound.

The shores of St. Charles's bay are generally high, but occasional points of marsh show as encroachments on the land from the bay. Lamar Point divides St. Charles's bay on the east side from Copano bay, which lies to the westward.

The town of Lamar is situated on the southern end of the point, fronting Lamar harbor, and on ground about twenty-two feet above the water, from which the surface slopes about a hundred metres. Towards the base of the front the slope is quite gradual. Three miles back from Lamar Point there is a strip of salt marsh a quarter of a mile in width, and extending

from the mouth of Cavasso creek, on St. Charles's bay, to the head of Copano bay. A "mott" of live-oak, occupying about a square mile and a half, stands immediately back of the town of Lamar. * * * * *

The character of the topography of the islands on the Gulf coast is prairie, covered in spots by mesquite bushes. A range of sand hills, some from twenty to thirty feet in height, and a third of a mile wide, follows the Gulf shore. The inside, or bay shores of these islands, are soft marsh, and are overflowed by high tides. The northeast end of St. Joseph's island is mostly bare, and is used in part for salt vats. A few fresh water ponds supply drink for the cattle kept on the island. The bay shore of the mainland is also marsh, broken occasionally by sand and shell banks, which are covered with a variety of bushes. The line of high ground follows the shore irregularly, leaving a strip of marsh about half a mile wide. * * *

The shell islands in Aransas bay are generally void of vegetation. Mud island is the largest. Its north shore is a shell bank, covered at intervals with bushes and palmettoes, and thence to the south shore the surface is very soft marsh, and the shore-line is broken into patches. * * *

Very respectfully, your obedient servant,

WYLLYS S. GILBERT,
Sub-Assistant U. S. Coast Survey.

Prof. A. D. BACHE,
Supt. U. S. Coast Survey.

APPENDIX No. 34.

Extracts from the report of Assistant S. A. Gilbert, descriptive of the shores of Corpus Christi bay, and Laguna Madre, Texas.

ZANESVILLE, *Ohio, August* 1, 1860.

DEAR SIR:

* * * The general features of the country are similar to those parts of the coast of Texas lying to the northward which have been described in previous reports of work in this section. The sand hills on the islands which form the Gulf shore abreast of Corpus Christi bay are generally higher than those between it and Matagorda entrance, and extend further back from the beach. On Padre island they occupy nearly its whole width. The bluffs on the mainland are also higher above the Gulf level. There is but very little low or marshy land on the mainland sides of Corpus Christi bay, or of the Laguna Madre. At Flour Bluff the elevation of the general level of the prairie above the bay is about ten feet, but at the head of Nueces bay it is about fifty feet.

At present there are but two families residing on Mustang island, and only two on the upper end of Padre island. On the mainland side of Laguna Madre there are no settlements for forty miles, and I am told that there is but one between Corpus Christi bay and Point Isabel.

Corpus Christi, on the south shore of the bay, is the principal port between Indianola and Brazos Santiago. The trade into and from Corpus Christi bay is chiefly carried on by steamboats and small lighters through Aransas and Espiritu Santo bays to Indianola, and by schooners to the Florida coast and New York. The last named class of vessels enter the bay by Aransas Pass, and find way through a channel made by private enterprise into Corpus Christi bayou, and across what are known as the "Mud flats." This line of communication now affords six feet of water to the wharves at Corpus Christi. The exports are hides and wool, and a little cotton.

The village of Ingleside is settled by the owners of stock ranches. It contains a seminary for the education of youth of both sexes, which seems to be well patronized by the residents of that part of the State. The village is situated on the north shore of the bay, and nearly opposite to the town of Corpus Christi. Its location is pleasant and healthy, and there is an abundance of pure fresh water from springs which issue from the bluff, some twenty to thirty feet below the surface of the prairie.

The north end of the Laguna Madre is a sand flat, extending five miles to the southward from the lower waters of Corpus Christi bay. On it the depth of water varies from nothing to fifteen inches, according to the direction and strength of the wind. After a norther has blown for a few hours there is no water, and the flats remain bare or only slightly covered until a southerly wind brings it back again. On the island side the flat is about a mile to a mile and a half wide throughout the entire range of forty miles, and at that distance from its northern end the laguna again shoals all the way across. On the mainland side the flat is about half a mile wide. The average width of Laguna Madre, including Padre island, or the distance from the Gulf beach to the mainland of Texas, is about four miles and a half. * * * *

Respectfully yours,

SAM'L A. GILBERT,
Assistant Coast Survey.

Prof. A. D. BACHE,
Supt. U. S. Coast Survey.

APPENDIX No. 35.

Supplement to Appendix No. 61 *in C. S. Report for* 1856, *on the "method of testing a repeating theodolite."*

In that portion of Appendix No. 61 in C. S. Report for 1856, which treats of the examination of eccentricity and graduation, the omission of the negative sign in one of the normal equations constitutes an error, which, having entered into the computation of the example there given, vitiates the results obtained. The object of the present article is to give a corrected statement of the former one, and, at the same time, a fuller development of the formulæ than was there introduced.

The instrument under examination was a ten-inch repeating theodolite, C. S. No. 79, constructed by Mr. William Wurdemann, and graduated on the Coast Survey dividing engine.

For the purpose of examining the graduation and determining the eccentricity of the alhidade, readings of the two verniers were made at each 10° of the graduation, vernier A being set each time to the precise reading; the circle was brought round 180° for the purpose of reading B under the same illumination, and, after setting the verniers forward 10°, the circle was moved back through that angle, so that the person reading did not change his position.

With the exception of this mode of taking the readings, the method here detailed will, of course, apply equally to a non-repeating instrument. The readings so taken are recorded below in Table I, where they are arranged in two sets, those readings differing 180° being placed on the same line.

TABLE I.

Readings of every ten degrees on the circle, and determination of angular distance of verniers.

I.		II.		B — A.		
A.	B.	A.	B.	I.	II.	Mean.
° ′ ″	″	° ′ ″	″	″	″	″
0 00 00	10	180 00 00	55	+ 10	— 5	+ 2.5
10 00 00	10	190 00 00	00	+ 10	0	+ 5.0
20 00 00	05	200 00 00	00	+ 5	0	+ 2.5
30 00 00	05	210 00 00	00	+ 5	0	+ 2.5
40 00 00	05	220 00 00	05	+ 5	+ 5	+ 5.0
50 00 00	05	230 00 00	05	+ 5	+ 5	+ 5 0
60 00 00	05	240 00 00	05	+ 5	+ 5	+ 5.0
70 00 00	05	250 00 00	05	+ 5	+ 5	+ 5.0
80 00 00	05	260 00 00	05	+ 5	+ 5	+ 5.0
90 00 00	05	270 00 00	00	+ 5	0	+ 2.5
100 00 00	05	280 00 00	00	+ 5	0	+ 2.5
110 00 00	05	290 00 00	00	+ 5	0	+ 2.5
120 00 00	05	300 00 00	00	+ 5	0	+ 2.5
130 00 00	05	310 00 00	00	+ 5	0	+ 2.5
140 00 00	00	320 00 00	05	0	+ 5	+ 2.5
150 00 00	00	330 00 00	10	0	+ 10	+ 5.0
160 00 00	55	340 00 00	10	— 5	+ 10	+ 2.5
170 00 00	55	350 00 00	10	— 5	+ 10	+ 2 5

Angular distance of verniers = 180° + 3″.5.

The differences of the readings of verniers A and B may be due, *first*, to their constant angular distance, being slightly more or less than 180°, which we will designate by $180 + \lambda$; *secondly*, to eccentricity of the alhidade, or the centre of its axis not coinciding precisely with the centre of the graduated circle; *thirdly*, to errors of graduation on the circle; and *fourthly*, to the accidental errors of reading. If we designate by μ the effect of eccentricity on the difference of the verniers, we have for any position of the verniers, $B - A = 180° + \lambda + \mu$; and, for a position differing 180° from the former, $B - A = 180° + \lambda - \mu$. Thus, if we take the mean of the differences B — A for readings differing 180°, as placed in juxtaposition in the table, this mean will express the angular distance of the verniers cleared of the effect of eccentricity, but each value affected by errors of graduation and reading. The column *mean*, under B — A, gives these values, the mean of which is + 3″.5, showing that the zero on vernier B is distant from that on vernier A by 180° 00′ 03″.5.

In order to determine next the eccentricity of the instrument, we subtract from the differences B — A in Table I the constant difference + 3″.5 of the verniers. The residuals will be composed of the effect of eccentricity and accidental errors of graduation and reading, and are given in Table II under the head μ + m. If we now designate by ε the angular value of the eccentricity, or the distance of the centre of graduation from that of motion, expressed in seconds of arc for the radius of the graduated circle, and by ρ that reading on the limb, which would be designated by a line passing from the centre of graduation through that of motion to the limb, then $(r - \rho)$ is the angle which the verniers make for any reading r, with the line of eccentricity, and $2\,\varepsilon \sin. (r - \rho) = \mu$ will be the effect of eccentricity in the differences of the vernier readings. Moreover, for any reading r' differing 180° from r the effect of eccentricity will be the same in amount as for r, but with the opposite sign, or $\mu' = -2\,\varepsilon \sin. (r - \rho.)$ In Table II, therefore, the values in column I and II should be respectively equal, with opposite signs, if they were not affected by the accidental errors m. The next column gives σ = half the difference of the preceding values, (or their mean, after changing the signs

in II,) which correspond to $\mu = 2\,\varepsilon$ sin. $(r - \rho)$ affected in a less degree by the accidental errors of reading and graduation.

In order to derive the values of ε and ρ from those of σ in the table, we observe that they correspond respectively to the following equations :

For 0°, $\sigma_1 = 2\,\varepsilon$ sin. $(0^\circ - \rho) = 2\,\varepsilon$ (sin. 0° cos. ρ — cos. 0° sin. ρ.)
For 10°, $\sigma_2 = 2\,\varepsilon$ sin. $(10^\circ - \rho) = 2\,\varepsilon$ (sin. 10° cos. ρ — cos. 10° sin. ρ.)
For 170°, $\sigma_{18} = 2\,\varepsilon$ sin. $(170 - \rho) = 2\,\varepsilon$ (sin. 170° cos. ρ — cos. 170° sin. ρ.)
Of which equations we have 18, or half the number of readings made.

In order to resolve these equations with reference to $2\,\varepsilon$ cos. ρ and $2\,\varepsilon$ sin. ρ by the method of least squares, we multiply each, first with the coefficient of cos. ρ, and next with the coefficient of sin. ρ, and taking the sums of the sets of equations so obtained, we shall have the two following *normal equations :*

$$[\sigma_1 \text{ sin. } 0^\circ + \sigma_2 \text{ sin. } 10^\circ + \ldots \sigma_{18} \text{ sin. } 170^\circ] = 2\,\varepsilon \text{ cos. } \rho\, [\text{sin. }^2 0^\circ + \text{sin. }^2 10^\circ + \ldots\ldots \text{sin. }^2 170^\circ.]$$
$$- 2\,\varepsilon \text{ sin. } \rho\, [\text{sin. } 0^\circ \text{ cos. } 0^\circ + \text{sin. } 10^\circ \text{ cos. } 10^\circ + \ldots \text{sin. } 170^\circ \text{ cos. } 170^\circ.]$$
$$[\sigma_1 \text{ cos. } 0^\circ + \sigma_2 \text{ cos. } 10^\circ + \ldots \sigma_{18} \text{ cos. } 170^\circ] = 2\,\varepsilon \text{ cos. } \rho\, [\text{cos. } 0^\circ \text{ sin. } 0^\circ + \text{cos. } 10^\circ \text{ sin. } 10^\circ + \ldots \text{cos. } 170^\circ \text{ sin. } 170^\circ.]$$
$$- 2\,\varepsilon \text{ sin. } \rho\, [\text{cos. }^2 0^\circ + \text{cos. }^2 10^\circ + \ldots \text{cos. }^2 170^\circ.]$$

It is readily seen that the sum of the series of products sin. 0° cos. 0° + sin. 10° cos. 10° + ... sin. 170° cos. 170° equals *zero*, as any two terms equidistant from 90° in opposite quadrants cancel each other.

Moreover, since sin. ^2r + sin. $^2(90^\circ + r) = 1$, the sum of the series sin. $^2 0^\circ$ + sin. $^2 10^\circ$ + ... sin. $^2 170^\circ$, consisting of n terms, is equal to $\frac{1}{2}\,n$; and equally cos. $^2 0^\circ$ + cos. $^2 10^\circ$ + ... cos. $^2 170^\circ = \frac{1}{2}\,n$. The normal equations, therefore, reduce to

$$\Sigma\ (\sigma \text{ sin. } r) = n\,\varepsilon \text{ cos. } \rho.$$
$$\Sigma\ (\sigma \text{ cos. } r) = -\,n\,\varepsilon \text{ sin. } \rho.$$

The first members of which expressions are the sums of the products of the several values of σ into the sines and cosines of the corresponding angles on the limb. Table II gives these sines, cosines, and products, and the sums of the latter.

Dividing the second by the first equation, we find

$$\text{tang.}\,\rho = \frac{-\,\Sigma(\sigma \text{ cos. } r)}{\Sigma(\sigma \text{ sin. } r)} = \frac{-\,33.4}{+\,6.5} = \text{tan. } 101^\circ, \text{ and } \rho = 101^\circ.$$

$$\text{For } \varepsilon \text{ we have further, } \varepsilon \text{ sin. } 101^\circ = \frac{-\,33.4}{18}, \text{ and } \varepsilon = -\,1''.9.$$

In regard to the interpretation of the signs, it may be observed that, since we have considered only the first half of the circle, the sign of tan. ρ will determine in which quadrant ρ is to be found, while the sign of ε will indicate when *positive* that the centre of motion is in the direction from the centre of graduation towards the reading ρ; when *negative*, that it is in the opposite direction.

TABLE II.

Determination of excentricity.

r.	$\mu + m$. I.	$\mu + m$. II.	$\frac{\text{I} - \text{II}}{2} = \sigma$	Sin. r.	Cos. r.	σ Sin. r.	σ Cos. r.
°	″	″	″			″	″
0	+ 6.5	− 8.5	+ 7.5	0.00	1.00	0 0	+ 7.5
10	+ 6 5	− 3.5	+ 5.0	.17	.98	+ 0.9	+ 4.9
20	+ 1.5	− 3.5	+ 2.5	.34	.94	+ 0.9	+ 2.3
30	+ 1.5	− 3.5	+ 2.5	.50	.87	+ 1.2	+ 2.2
40	+ 1.5	+ 1.5	0.0	.64	.76	0.0	0.0
50	+ 1.5	+ 1 5	0.0	.76	.64	0.0	0.0
60	+ 1.5	+ 1.5	0.0	.87	.50	0.0	0.0
70	+ 1.5	+ 1.5	0.0	.94	.34	0.0	0.0
80	+ 1.5	+ 1.5	0 0	.98	.17	0.0	0.0
90	+ 1.5	− 3.5	+ 2.5	1.00	.00	+ 2.5	0.0
100	+ 1.5	− 3.5	+ 2.5	.98	− .17	+ 2.5	− 0.4
110	+ 1.5	− 3.5	+ 2.5	.94	− .34	+ 2.3	− 0.8
120	+ 1.5	− 3.5	+ 2.5	.87	− .50	+ 2.2	− 1.2
130	+ 1.5	− 3.5	+ 2.5	.76	− .64	+ 1.9	− 1.6
140	− 3.5	+ 1.5	− 2.5	.64	− .76	− 1.6	+ 1.9
150	− 3.5	+ 6.5	− 5.0	.50	− .87	− 2.5	+ 4.3
160	− 8.5	+ 6.5	− 7.5	.34	− .94	− 2.5	+ 7.0
170	− 8.5	+ 6.5	− 7.5	.17	− .98	− 1.3	+ 7.3
						+14.4	+37.4
						− 7.9	− 4.0
						+ 6.5	+33.4

To determine the residual errors of graduation and reading, we form Table III by computing $\mu = 2\,\varepsilon \sin. (r - \rho)$ for each reading, and subtracting these values of μ from those of $\mu + m$ in Table II, bearing in mind that μ has the same value for $180° + r$ as for r, with reversed sign. We thus obtain the values of m, which are compounded of two errors of graduation and reading combined, being the difference of readings of verniers A and B, cleared of λ and μ.

TABLE III.

Residual errors of graduation and readings.

r.	$r - \rho$	$2\,\varepsilon$ sin. $(r - \rho)$	r.	m.	r.	m.
°	°	″	°	″	°	″
0	− 101	+ 3.7	0	+ 2.8	180	− 4.8
10	− 91	+ 3.8	10	+ 2.7	190	+ .3
20	− 81	+ 3.7	20	− 2.2	200	+ .2
30	− 71	+ 3.6	30	− 2.1	210	+ .1
40	− 61	+ 3.3	40	− 1.8	220	+ 4.8
50	− 51	+ 2.9	50	− 1.4	230	+ 4.4
60	− 41	+ 2.5	60	− 1.0	240	+ 4.0
70	− 31	+ 1.9	70	− .4	250	+ 3.4
80	− 21	+ 1.3	80	+ .2	260	+ 2.8
90	− 11	+ .7	90	+ .8	270	− 2.8
100	− 1	+ .0	100	+ 1.5	280	− 3.5
110	+ 9	− .6	110	+ 2.1	290	− 4.1
120	+ 19	− 1.2	120	+ 2.7	300	− 4.7
130	+ 29	− 1.8	130	+ 3.3	310	− 5.3
140	+ 39	− 2.4	140	− 1.1	320	− .9
150	+ 49	− 2.8	150	− .7	330	+ 3.7
160	+ 59	− 3.2	160	− 5.3	340	+ 3.3
170	+ 69	− 3.5	170	− 5.0	350	+ 3.0

The sum of the squares of the thirty-six residuals m is 334; hence the mean uncertainty of one is $\sqrt{\frac{334}{35}} = \pm\ 9''.1$, which, divided by the square root of two, gives $\pm\ 2''.2$ as the mean uncertainty of the indication of one vernier, as depending on accidental errors of reading and graduation. The same uncertainty is to be ascribed to an angle resulting from the subtraction of the mean of two vernier readings from another mean; and when such an angle is the sum of six repetitions, the uncertainty from those sources to be ascribed to the single angle is one-sixth of $\pm\ 2''.2$ or $\pm\ 0''.4$. We have thus ascertained that the angular distance of the verniers is 180° 00′ 03″.5; that the eccentricity of the centre of motion is 1″.9 in the direction from the centre of graduation to the reading of 281° on the limb, and that the mean uncertainty of the indication of one vernier is $\pm\ 2''.2$.

APPENDIX No. 36.

Formulæ, tables, and example for the geodetic computation of latitudes, longitudes, and azimuths of trigonometrical points, as used in the United States Coast Survey.

The computation of the latitude, longitude, and azimuth of the geodetic points of the survey is effected by means of the following formulæ and auxiliary tables. The latter depend on Bessel's value of the magnitude and figure of the earth, viz:

Equatorial radius, a = 3272077.14 toises = 6377397.16 metres.

Polar radius b, = 3261139.33 toises = 6356078.96 metres.

The adopted unit of length for the distances is the metre.

Let K = the given geodetic distance between two trigonometrical points; L = the given latitude of the first point; M = the given longitude of the same; Z = the given azimuth of the first to the second point, counted from south round by west; and let L^1, M^1, Z^1 = the required latitude, longitude, and azimuth for the second point; also let d L, d M, d Z = the difference in latitude, longitude, and azimuth of the two points and expressed in seconds of arc.

We then have (without material error) for distances not exceeding one hundred miles—

$$-\,d\,L = K\,B\cos.\,Z + K^2\,C\sin.^2 Z + (\delta\,L)^2\,D - K^2\,h\,E\sin.^2 Z \quad\cdots\cdots\cdots\quad (1)$$

$$\text{where } B = \frac{1}{R\ \text{arc}\ 1''} \qquad C = \frac{\tan.\,L}{2\,N\,R\ \text{arc}\ 1''} \qquad D = \frac{\frac{3}{2}\,e^2\sin.\,L\cos.\,L\ \text{arc}\ 1''}{(1 - e^2\sin.^2 L)^{\frac{3}{2}}}$$

$$E = \frac{1 + 3\tan^2 L}{6\,N^2} \quad h = K\,B\cos.\,Z,\ \text{or first term.} \quad R = \frac{a\,(1 - e^2)}{(1 - e^2\sin.^2 L)^{\frac{3}{2}}}$$

$$N = \frac{a}{(1 - e^2\sin.^2 L)^{\frac{1}{2}}} \qquad e = \sqrt{\frac{a^2 - b^2}{a^2}} = 0.08169683$$

δ L = an approximate value for $-\,d$ L from first and second term.

$$d\,M = \frac{A^1\,K\sin.\,Z}{\cos.\,L^1} \quad\cdots\cdots\cdots\quad (2)$$

to which a small correction (see table) is to be applied for the difference in the arc and sine.

$$A^1 = \frac{1}{N\ \text{arc}\ 1''}$$ referring to the second point as indicated by the accented A.

$$-\,d\,Z = \frac{d\,M\sin.\,\lambda}{\cos.\,\frac{1}{2}\,d\,L} + d\,M^3\,F \quad\cdots\cdots\cdots\quad (3)$$

where $\lambda = \frac{1}{2}\,(L + L^1)$ and log. F for lat. 25° = 7.8324, and for lat. 45° = 7.8404. The quantities A, B, C, D, E, are given in the tables. In computing, carry log. A and log. B to seven

places of decimals, log. C to five, and log's D and E to four places; log. F to three places. The third term in equation (1) should be used whenever log. h exceeds 2.31, and h^2 may be used for $(\delta\ L)^2$ in all cases when K does not exceed 86,000 metres, (about 54 miles.) The fourth term in equation (1) may be omitted between latitudes 45° to 40°, when K does not exceed 17,000*m.* or log. K 4.2304; 40° to 35° when K does not exceed 18,500*m.* or log. K 4.2665; 35° to 30° when K does not exceed 20,000*m.* or log. K 4.3010.

In using formula (2) the subsidiary table should be referred to when K exceeds 27,000 metres, (about $16\frac{1}{2}$ miles.)

Table of corrections to longitude for difference in arc and sine.

Log. K (−)	Log. difference.	Log. d M (+)	Log. K (−)	Log. difference.	Log. d M (+)	Log. K (−)	Log. difference.	Log. d M (+)
3.871	0.0000001	2.380	4.732	0.0000052	3.241	5.033	0.0000206	3.542
3.970	02	2.479	4.746	056	3.255	5.040	213	3.549
4.115	03	2.624	4.761	059	3.270	5.047	221	3.556
4.171	04	2.680	4.774	063	3.283	5.054	228	3.563
4.221	05	2.730	4.788	067	3.297	5.062	236	3.571
4.268	06	2.777	4.801	071	3.310	5.068	243	3.577
4.292	07	2.801	4 813	075	3.322	5.075	251	3.584
4.309	08	2.818	4.825	080	3.334	5.082	259	3.591
4.320	09	2.839	4.834	083	3.343	5.088	267	3.597
4.361	10	2.870	4.849	089	3.358	5.095	275	3.604
4.383	11	2.892	4.860	094	3.369	5.102	284	3.611
4.415	12	2.924	4.871	098	3.380	5.108	292	3.617
4.430	13	2.939	4.882	103	3.391	5.114	300	3.623
4.445	14	2.954	4.892	108	3.401	5.120	309	3.629
4.459	15	2.968	4.903	114	3.412	5.126	218	3.635
4.473	16	2.982	4.913	119	3.422	5.132	327	3.641
4.487	17	2.996	4.922	124	3.431	5.138	336	3.647
4.500	18	3.009	4.932	130	3 441	5.144	345	3.653
4.524	20	3.033	4.941	136	3.450	5.150	354	3.659
4.548	23	3.057	4.950	142	3.459	5.156	364	3.665
4.570	25	3.079	4.959	147	3.468	5.161	373	3.670
4.591	27	3.100	4.968	153	3.477	5.167	383	3.676
4.612	30	3.121	4.976	160	3.485	5.172	392	3.681
4.631	33	3.140	4.985	166	3.494	5.178	402	3.687
4.649	36	3.158	4.993	172	3.502	5.183	412	3.692
4.667	39	3.176	5.002	179	3 511	5.188	422	3.697
4.684	42	3.193	5 010	186	3.519	5.193	433	3.702
4.701	45	3.210	5 017	192	3.526	5.199	443	3.708
4.716	48	3.225	5.025	199	3.534	5.204	453	3.713

In using this table, take out the differences for the arguments log. K and log. d M; the first difference with a negative, the second with a positive sign, and add the algebraic sum to the log. d M. The second term in formula (3) may generally be omitted; when K is less than 34,000 metres (21 miles;) cos. $\frac{1}{2}$ d K may also be omitted in computing d Z.

— d L and d M should be computed to thousandths of seconds, and — d Z to hundredths, for which purpose six places of decimals suffice in the term for computing d Z.

For convenience the value log. ar. co. cos. $\frac{1}{2}$ d L has also been tabulated, the argument being d L.

dL	$\log.\frac{1}{\cos.\frac{1}{2}dL}$	dL	$\log.\frac{1}{\cos.\frac{1}{2}dL}$	dL	$\log.\frac{1}{\cos.\frac{1}{2}dL}$	dL	$\log.\frac{1}{\cos.\frac{1}{2}dL}$	dL	$\log.\frac{1}{\cos.\frac{1}{2}dL}$
′		′		′		′		′	
10	0.000000	28	0.000004	46	0.000010	64	0.000019	82	0.000031
11	1	29	4	47	10	65	19	83	32
12	1	30	4	48	11	66	20	84	32
13	1	31	4	49	11	67	21	85	33
14	1	32	5	50	11	68	21	86	34
15	1	33	5	51	12	69	22	87	35
16	1	34	5	52	12	70	22	88	36
17	1	35	6	53	13	71	23	89	36
18	1	36	6	54	13	72	24	90	37
19	2	37	6	55	14	73	24	91	38
20	2	38	7	56	14	74	25	92	39
21	2	39	7	57	15	75	26	93	40
22	2	40	7	58	15	76	26	94	41
23	2	41	8	59	16	77	27	95	41
24	3	42	8	60	16	78	28	96	42
25	3	43	8	61	17	79	29	97	43
26	3	44	9	62	18	80	29	98	44
27	3	45	9	63	18	81	30	99	45

For secondary triangulation, and when the sides do not exceed about twelve miles, the following formulæ for the computation of latitude, longitude, and azimuth may be used advantageously:

$$-d\,\mathrm{L} = \mathrm{K\,B}\cos.\,\mathrm{Z} + \mathrm{K}^2\,\mathrm{C}\sin.^2\mathrm{Z} + h^2\,\mathrm{D} \quad \cdots\cdots \quad (4)$$

$$d\,\mathrm{M} = \frac{\mathrm{A}^1\,\mathrm{K}\sin.\,\mathrm{Z}}{\cos.\,\mathrm{L}^1} \quad \cdots\cdots \quad (5)$$

$$-d\,\mathrm{Z} = d\,\mathrm{M}\sin.\,\lambda \quad \cdots\cdots \quad (6)$$

where the letters have the same signification as before. When log. h is less than 2.31, the third term in equation (4) may be omitted. In the computation carry log. A and log. B to seven places of decimals, log. C to five, and log. D to four places. In computing $-d\,\mathrm{Z}$ the log's $d\,\mathrm{M}$ and sin. λ should be taken to five places for the main chain of triangles, and to four places for subordinate points.

$-d\,\mathrm{L}$ and $d\,\mathrm{M}$ should be computed to thousandths of seconds, as before; $-d\,\mathrm{Z}$ to tenths, and for subsidiary points the nearest full second suffices.

The two following examples of the computation of the position of a primary and secondary point will further illustrate the use of the tables:

		°	′	″
Z	Mount Blue to Mount Pleasant....	26	19	27.01
$\angle$	Mount Pleasant and Ragged	—85	35	25.67
Z	Mount Blue to Ragged	300	44	01.34
d Z		+	50	04.21
180				
Z′	Ragged to Mount Blue	121	34	05.55

	°	′	″			°	′	″
L	44	43	40.121	Mount Blue	M	70	20	11.921
d L	—	30	56.166	110740.6 metres, (68.8 miles, nearly)	d M	—1	11	28.343
L′	44	12	43.955	Ragged	M′	69	08	43.578

K	5.0443070	K²	10.08861			h	3.2633+
Cos. Z	9.7084622+	Sin² Z	9.86854	(δ L²)	6.5373	K² sin² Z	9.9571
B	8.5105331	C	1.40002	D	2.3872	E	6.2070
h	3.2633023+		1.35717		8.9245		9.4274+
1st term	+1833.590	3d term.	+ 0.084			d M²	10.897—
2d term	22.760	—4th term.	— 0.268			F	7.840
	+1856.350						8.737—
3d & 4th terms	— 0.184						
d L	+1856.166	A′	8.5090758	Arg.		d M	3.632289—
λ	44° 28′ 12″.0	K	5.0443070	K	—218	Sin λ	9.845430
		Sin Z	9.9342721—	d M u	+314	Cos. ½ d L ar. co.	0.000004
		Cos. L′ ar. co.	0.1446250				3.477723—
			3.6322895—	corr.	+ 96	—d Z	— 3004.16
		d M	— 4288.343			2d term.	— 0.05

		°	′	″
Z	Tomales Bay to Sonoma	244	08	27.3
∠	Sonoma and Bodega	— 83	14	36.8
Z	Tomales Bay to Bodega	160	53	50.5
d Z		—	2	02.0
180				
Z′	Bodega to Tomales Bay	340	51	48.5

	°	′	″			°	′	″
L	38	10	52.524	Tomales bay	M	122	55	48.380
d L	+	7	28.257	14626.8 metres	d M	+	3	17.040
L′	38	18	20.781	Bodega	M′	122	59	05.420

λ = 38° 14′ 37″		K	4.1651480	K²	8.33030		
		B	8.5110266	C	1.30044	D	2.3743
		Cos. Z	9.9754014—	Sin² Z	9.02979	h²	5.3031
1st term	—448.308	h	2.6515760—		8.66053		7.6774
2d & 3d term	+ 0.051						
—d L	—448.257						

K	4.1651480		
Sin Z	9.5148949+		
A′	8.5092241	d M	2.29456+
Cos. L′ Ar. Comp.	0.1052885	Sin λ	9.79169
	2.2945555+		2.08625+
d M	+197.040″	—d Z	+122.0″

LATITUDE 23 DEGREES.

Latitude.	Log. A. diff. 10″ = −0.5. *	Log. B. diff. 10″ = −1.5. *	Log. C. diff. 10″ = +5.8. *	Log. D. diff. 10″ = +0.4. *	Log. E. diff. 10″ = +0.4. *
° ′					
23 00	8.50956029	8.51202588	1.033983	2.24264	5.79979
1	5998	2497	4332	289	5.80004
2	5968	2405	4681	313	028
3	5938	2314	5030	338	053
4	5907	2223	5379	362	078
5	5877	2132	5728	386	102
6	5846	2040	6077	411	127
7	5816	1949	6426	435	152
8	5785	1858	6775	459	176
9	5755	1766	7124	484	201
10	8.50955724	8.51201675	1.037473	2.24508	5 80226
11	5694	1583	7821	532	250
12	5663	1491	8168	556	275
13	5633	1400	8515	580	300
14	5602	1308	8862	604	325
15	5571	1216	9209	629	350
16	5541	1124	9556	653	374
17	5510	1032	9903	677	399
18	5480	0941	1.040250	701	424
19	5449	0849	0597	725	449
20	8.50955418	8.51200757	1.040944	2.24749	5.80473
21	5387	*0664	1290	773	498
22	5357	0572	1635	796	523
23	5326	0480	1980	820	548
24	5295	0387	2325	844	573
25	5264	0295	2670	868	598
26	5234	0203	3016	892	623
27	5203	0110	3361	915	648
28	5172	0018	3706	939	672
29	5141	8.51199926	4051	963	697
30	8.50955110	8.51199833	1.044396	2.24987	5.80722
31	5080	9740	4740	2.25010	747
32	5049	9648	5083	034	772
33	5018	9555	5426	057	797
34	4987	9462	5769	081	822
35	4956	9369	6113	104	847
36	4925	9276	6456	128	872
37	4894	9183	6799	151	897
38	4863	9090	7143	175	922
39	4832	8998	7486	198	947
40	8 50954801	8.51198905	1.047829	2.25222	5.80972
41	4770	8811	8171	245	997
42	4739	8718	8512	268	5.81022
43	4708	8625	8854	292	047
44	4677	8531	9195	315	073
45	4645	8438	9537	338	098
46	4614	8345	9878	361	123
47	4583	8251	1.050220	385	148
48	4552	8158	0561	408	173
49	4521	8065	0902	431	198
50	8.50954490	8.51197971	1.051244	2.25454	5.81223
51	4459	7877	1584	477	249
52	4427	7784	1923	500	274
53	4396	7690	2263	523	299
54	4365	7596	2603	546	324
55	4333	7502	2942	569	350
56	4302	7408	3282	592	375
57	4271	7314	3621	615	400
58	4240	7220	3961	638	425
59	4208	7127	4301	661	450
60	8.50954177	8.51197033	1.054640	2.25684	5.81476

* Throughout the tables the differences of 10″, in log's A, B, C, D, E, refer to one place of decimals less than is given in their tabular values.

LATITUDE 24 DEGREES.

Latitude.	Log. A. diff. 10″ = — 0.5.	Log. B. diff. 10″ = — 1.6.	Log. C. diff. 10′ = + 5.6.	Log. D. diff. 10″ = + 0.4.	Log. E. diff. 10″ = + 0.4.
° ′					
24 00	8.50954177	8.51197033	1.054640	2.25684	5.81476
1	4146	6938	4978	707	501
2	4114	6844	5316	730	526
3	4083	6750	5654	752	552
4	4051	6655	5991	775	577
5	4020	6561	6329	798	603
6	3988	6467	6667	820	628
7	3957	6372	7005	843	653
8	3925	6278	7343	866	679
9	3894	6184	7681	888	704
10	8.50953862	8.51196089	1.058019	2.25911	5.81729
11	3831	5995	8355	934	755
12	3799	5900	8691	956	780
13	3768	5805	9027	979	806
14	3736	5710	9363	2.26001	831
15	3704	5615	9699	023	857
16	3673	5520	1.060035	046	882
17	3641	5426	0371	068	908
18	3610	5331	0707	090	933
19	3578	5236	1043	2.26113	958
20	8.50953546	8.51195141	1.061379	2.26135	5.81984
21	3515	5046	1714	158	5.82009
22	3483	4950	2048	180	035
23	3451	4855	2383	202	061
24	3419	4760	2717	225	086
25	3388	4664	3051	247	112
26	3356	4569	3386	269	137
27	3324	4474	3720	291	163
28	3292	4378	4054	313	189
29	3260	4283	4389	335	214
30	8.50953229	8.51194188	1.064723	2.26357	5.82240
31	3197	4092	5056	379	266
32	3165	3996	5388	401	291
33	3133	3900	5721	423	317
34	3101	3805	6054	445	343
35	3069	3709	6386	467	368
36	3037	3613	6719	489	394
37	3005	3517	7052	511	420
38	2973	3421	7384	533	445
39	2941	3326	7717	555	471
40	8.50952909	8.51193230	1.068050	2.26577	5.82497
41	2877	3134	8381	599	523
42	2845	3037	8712	620	548
43	2813	2941	9043	642	574
44	2781	2845	9374	664	600
45	2749	2748	9705	685	626
46	2717	2652	1.070036	707	652
47	2685	2556	0367	729	677
48	2653	2460	0698	750	703
49	2620	2363	1029	772	729
50	8.50952588	8.51192267	1.071360	2.26794	5.82755
51	2556	2170	1689	815	781
52	2524	2073	2018	836	807
53	2492	1977	2348	858	833
54	2459	1880	2677	879	859
55	2427	1783	3006	901	884
56	2395	1686	3336	922	910
57	2363	1590	3665	944	936
58	2330	1493	3994	965	962
59	2298	1396	4324	986	988
60	8 50952266	8.51191299	1.074653	2.27008	5.83014

LATITUDE 25 DEGREES.

Lat.	Log. A. diff. 10″ = − 0.5.	Log. B. diff. 10″ = − 1.6.	Log. C. diff. 10″ = + 5.4.	Log. D. diff. 10″ = + 0.3.	Log. E. diff. 10″ = + 0.4.
° ′					
25 00	8.50952266	8.51191299	1.074653	2.27008	5.83014
1	2234	1202	4981	029	040
2	2201	1105	5309	050	066
3	2169	1008	5637	071	092
4	2136	0911	5965	092	118
5	2104	0814	6294	114	144
6	2072	0716	6621	135	170
7	2039	0619	6949	156	196
8	2007	0522	7276	177	222
9	1974	0425	7603	198	248
10	8.50951942	8.51190328	1 077930	2.27219	5.83274
11	1909	0230	8257	240	300
12	1877	0132	8583	261	327
13	1844	0034	8910	282	353
14	1812	8.51189936	9237	303	379
15	1779	9839	9563	324	405
16	1746	9741	9889	345	431
17	1714	9643	1.080215	366	457
18	1681	9546	0540	387	483
19	1649	9449	0866	408	510
20	8.50951616	8.51189350	1.081192	2.27429	5.83536
21	1583	9252	1517	449	562
22	1551	9153	1842	470	588
23	1518	9055	2167	491	615
24	1485	8957	2492	512	641
25	1452	8859	2817	532	667
26	1420	8761	3141	553	693
27	1387	8662	3465	573	719
28	1354	8564	3789	594	746
29	1322	8466	4113	615	772
30	8.50951289	8.51188368	1.084438	2.27635	5.83798
31	1256	8269	4761	656	824
32	1223	8171	5084	676	851
33	1190	8072	5408	696	877
34	1157	7973	5731	717	904
35	1124	7875	6055	737	930
36	1092	7776	6377	758	956
37	1059	7677	6700	778	983
38	1026	7579	7023	799	5.84009
39	0993	7480	7345	819	036
40	8.50950960	5.81187381	1.087668	2.27840	5.84062
41	0927	7282	7990	860	089
42	0894	7183	8312	880	115
43	0861	7084	8634	900	141
44	0828	6985	8955	921	168
45	0795	6886	9277	941	194
46	0762	6787	9599	961	221
47	0729	6688	9920	981	247
48	0696	6589	1.090241	2.28001	273
49	0663	6489	0562	022	300
50	8.50950630	8.51186390	1.090883	2.28042	5.84326
51	0597	6291	1204	062	353
52	0564	6191	1525	082	380
53	0530	6092	1845	102	406
54	0497	5992	2166	122	433
55	0464	5893	2487	141	460
56	0431	5793	2806	161	486
57	0398	5693	3125	181	513
58	0364	5594	3445	201	539
59	0331	5494	3764	221	566
60	8.50950298	8.51185395	1.094084	2.28241	5.84593

LATITUDE 26 DEGREES.

Latitude.	Log. A. diff. 10″ = — 0.6.	Log. B. diff. 10″ = — 1.7.	Log. C. diff. 10″ = + 5.3.	Log. D. diff. 10″ = + 0.3.	Log. E. diff. 10″ = + 0.45.
° ′					
26 00	8.50950298	8.51185395	1.094084	2.28241	5.84593
1	0265	5295	4403	261	619
2	0231	5195	4722	281	646
3	0198	5095	5040	300	673
4	0164	4995	5359	320	700
5	0131	4895	5678	340	726
6	0098	4795	5996	360	753
7	0064	4695	6315	379	780
8	0031	4595	6633	399	806
9	8.50949997	4495	6951	419	833
10	8.50949964	8.51184395	1.097269	2.28439	5.84860
11	9930	4294	7586	458	887
12	9897	4194	7904	478	913
13	9863	4094	8222	497	940
14	9830	3993	8539	517	967
15	9796	3892	8857	536	994
16	9763	3792	9174	555	5.85021
17	9730	3691	9490	575	048
18	9696	3591	9807	594	075
19	9663	3490	1.100124	614	101
20	8.50949629	8.51183390	1.100441	2.28633	5.85128
21	9596	3289	0757	653	155
22	9562	3188	1073	672	182
23	9528	3087	1389	691	209
24	9495	2986	1705	710	236
25	9461	2885	2021	730	263
26	9427	2784	2336	749	290
27	9394	2683	2652	768	316
28	9360	2582	2967	787	343
29	9327	2482	3283	807	370
30	8.50949293	8.51182381	1.103598	2.28826	5.85397
31	9259	2279	3912	845	424
32	9225	2178	4227	864	451
33	9192	2076	4542	883	478
34	9158	1975	4856	902	505
35	9124	1874	5171	921	532
36	9090	1772	5485	940	559
37	9056	1671	5799	959	586
38	9023	1570	6113	978	613
39	8989	1468	6427	997	640
40	8.50948955	8.51181367	1.106741	2.29016	5.85667
41	8921	1265	7054	035	694
42	8887	1163	7367	054	721
43	8853	1062	7681	073	748
44	8819	0960	7994	091	775
45	8785	0858	8308	110	802
46	8752	0756	8620	129	830
47	8718	0654	8933	148	857
48	8684	0553	9245	167	884
49	8650	0451	9558	185	911
50	8.50948616	8.51180349	1.109871	2.29204	5.85938
51	8582	0247	1.110183	223	965
52	8548	0145	0495	241	992
53	8514	0042	0807	260	5.86020
54	8480	8.51179940	1119	278	047
55	8446	9838	1430	297	074
56	8411	9736	1742	316	101
57	8377	9633	2053	334	129
58	8343	9531	2364	353	156
59	8309	9429	2676	371	183
60	8.50948275	8.51179327	1.112987	2.29390	5.86210

LATITUDE 27 DEGREES.

Latitude.	Log. A. diff. 10″ = −0.6.	Log. B. diff. 10″ = −1.7.	Log. C. diff. 10″ = +5.1.	Log. D. diff. 10″ = +0.3.	Log. E. diff. 10″ = +0.5.
° ′					
27 00	8.50948275	8.51179327	1.112987	2.29390	5.86210
1	8240	9224	3297	408	238
2	8207	9121	3608	427	265
3	8172	9019	3919	445	292
4	8138	8916	4229	463	320
5	8104	8813	4540	482	347
6	8070	8710	4850	500	374
7	8036	8608	5160	518	402
8	8001	8505	5470	537	429
9	7967	8402	5780	555	456
10	8.50947933	8.51178300	1.116090	2.29573	5.86484
11	7899	8197	6400	591	511
12	7864	8093	6708	610	539
13	7830	7990	7013	628	566
14	7795	7887	7327	646	593
15	7761	7784	7636	664	621
16	7727	7681	7945	682	648
17	7692	7578	8253	700	676
18	7658	7475	8562	718	703
19	7623	7372	8871	736	730
20	8.50947589	8.51177269	1.119179	2.29755	5.86758
21	7554	7165	9487	772	785
22	7520	7061	9795	790	813
23	7485	6958	1.120103	808	841
24	7451	6854	0411	826	868
25	7416	6751	0719	844	896
26	7382	6647	1027	862	923
27	7347	6544	1334	880	951
28	7313	6440	1642	898	978
29	7278	6337	1949	916	5.87006
30	8.50947244	8.51176233	1.122256	2.29934	5.87033
31	7209	6129	2563	951	61
32	7175	6025	2870	969	89
33	7140	5921	3176	988	116
34	7105	5817	3483	2.30004	144
35	7070	5713	3790	022	172
36	7035	5609	4096	040	199
37	7001	5505	4402	058	227
38	6966	5401	4708	075	255
39	6932	5297	5014	093	282
40	8.50946897	8.51175193	1.125320	2.30111	5.87310
41	6862	5089	5626	128	338
42	6827	4985	5931	146	363
43	6793	4880	6237	163	393
44	6758	4776	6542	180	421
45	6723	4671	6848	198	449
46	6688	4567	7153	215	476
47	6653	4463	7458	233	504
48	6619	4358	7763	250	532
49	6584	4254	8068	268	560
50	8.50946549	8.51174149	1.128373	2.30285	5.87587
51	6514	4045	8677	302	615
52	6479	3940	8981	320	643
53	6444	3835	9285	337	671
54	6409	3730	9589	354	699
55	6374	3626	1.129894	371	727
56	6340	3521	1.130197	389	754
57	6305	3416	0501	406	782
58	6270	3311	0805	423	810
59	6235	3206	1109	440	838
60	8.50946200	8.51173102	1.131412	2.30458	5.87866

LATITUDE 28 DEGREES.

Latitude.	Log. A. diff. 10″ = − 0.6.	Log B. diff. 10″ = − 1.8.	Log. C. diff. 10′ = + 5.0.	Log. D. diff. 10″ = + 0.3.	Log. E. diff. 10″ = +0.5.
° ′					
28 00	8.50946200	8.51173102	1.131412	2.30458	5.87866
1	6165	2996	1715	475	894
2	6130	2891	2018	492	922
3	6095	2786	2321	509	950
4	6060	2681	2624	526	977
5	6025	2576	2927	543	5.88005
6	5989	2470	3230	560	033
7	5954	2365	3533	577	061
8	5919	2260	3835	594	089
9	5884	2155	4137	611	117
10	8.50945849	8.51172050	1.134440	2.30628	5.88145
11	5814	1944	4742	645	173
12	5779	1838	5044	662	201
13	5744	1733	5346	679	229
14	5709	1627	5648	696	257
15	5673	1521	5949	712	285
16	5638	1416	6251	729	313
17	5603	1310	6552	746	342
18	5568	1204	6853	763	370
19	5532	1099	7155	780	398
20	8.50945497	8.51170993	1.137456	2.30797	5.88426
21	5462	0887	7757	813	454
22	5426	0781	8057	830	482
23	5391	0675	8358	846	510
24	5356	0569	8659	863	538
25	5320	0462	8959	880	566
26	5285	0357	9259	896	595
27	5250	0251	9560	913	623
28	5215	0145	9860	930	651
29	5179	0039	1.140160	946	679
30	8.50945144	8.51169933	1.140460	2.30963	5.88707
31	5109	9827	0760	979	736
32	5073	9720	1059	996	764
33	5038	9614	1359	2.31012	792
34	5002	9507	1658	028	820
35	4967	9401	1958	045	849
36	4931	9294	2257	061	877
37	4896	9188	2556	078	905
38	4860	9081	2855	094	931
39	4825	8975	3154	110	962
40	8.50944789	8.51168869	1.143453	2.31127	5.88990
41	4753	8762	3751	143	5.89019
42	4718	8655	4050	159	047
43	4682	8548	4348	175	075
44	4647	8441	4647	192	103
45	4611	8334	4945	208	132
46	4575	8228	5243	224	160
47	4540	8121	5541	240	188
48	4504	8014	5839	256	217
49	4469	7907	6137	273	245
50	8.50944433	8.51167800	1.146434	2.31289	5.89274
51	4397	7693	6732	305	302
52	4361	7586	7029	321	330
53	4326	7479	7326	337	359
54	4290	7371	7624	353	387
55	4254	7264	7921	369	416
56	4218	7157	8218	385	445
57	4183	7050	8515	401	473
58	4147	6942	8811	417	502
59	4111	6835	9108	433	530
60	8.50944075	8.51166728	1.149405	2.31449	5.89558

LATITUDE 29 DEGREES.

Latitude.	Log. A. diff. 10″ = — 0.6.	Log. B. diff. 10″ = — 1.8.	Log. C. diff. 10″ = + 4.9.	Log. D. diff. 10″ = + 0.3.	Log. E. diff. 10″ = + 0.5.
° ′					
29 00	8.50944075	8.51166728	1.149405	2.31449	5.89558
1	4039	6620	9701	465	587
2	4004	6513	9997	480	615
3	3968	6405	1.150294	496	644
4	3932	6297	0590	512	672
5	3896	6190	0886	528	701
6	3860	6082	1182	544	730
7	3824	5975	1477	559	758
8	3788	5867	1773	575	787
9	3752	5759	2069	591	815
10	8.50943717	8.51165652	1.152364	2.31607	5.89844
11	3681	5544	2660	622	873
12	3645	5436	2955	638	901
13	3609	5328	3250	653	930
14	3573	5220	3545	669	958
15	3537	5112	3840	685	987
16	3501	5004	4135	700	5.90016
17	3465	4896	4430	716	044
18	3429	4788	4724	631	073
19	3393	4680	5019	747	102
20	8.50943357	8.51164572	1.155313	2.31763	5.90131
21	3320	4463	5607	778	159
22	3284	4355	5902	793	188
23	3248	4246	6196	809	217
24	3212	4138	6490	824	246
25	3176	4030	6784	840	274
26	3140	3921	7078	855	303
27	3104	3813	7371	870	332
28	3067	3704	7665	886	361
29	3031	3596	7958	901	390
30	8.50942995	8.51163488	1.158252	2.31917	5.90418
31	2959	3379	8545	932	447
32	2923	3270	8838	947	476
33	2886	3161	9131	962	505
34	2850	3052	9424	977	534
35	2814	2944	9717	993	563
36	2778	2835	1.160010	2.32009	592
37	2741	2726	0302	023	620
38	2705	2617	0595	038	649
39	2669	2508	0887	053	678
40	8.50942633	8.51162400	1.161180	2.32068	5.90707
41	2597	2291	1472	083	736
42	2560	2181	1764	098	765
43	2524	2072	2056	113	794
44	2487	1963	2348	128	823
45	2451	1854	2640	143	853
46	2415	1745	2932	158	881
47	2378	1636	3223	173	910
48	2342	1527	3515	188	939
49	2305	1417	3806	203	968
50	8.50942269	8.51161308	1.164098	2.32218	5.90997
51	2232	1199	4389	233	5.91026
52	2196	1089	4680	248	055
53	2159	0980	4971	263	084
54	2123	0870	5262	278	113
55	2086	0761	5553	292	142
56	2050	0651	5843	307	171
57	2013	0542	6134	322	200
58	1977	0432	6424	337	229
59	1940	0323	6715	352	258
60	8.50941904	8.51160213	1.167005	2.32366	5.91287

LATITUDE 30 DEGREES.

Latitude.	Log. A. diff. 10″=−0.6.	Log. B. diff. 10″=−1.8.	Log. C. diff 10″=+4.8.	Log. D. diff. 10″=+0.2.	Log. E. diff. 10″=+0.5.
° ′					
30 00	8.50941904	8.51160213	1.167005	2.32366	5.91287
1	1867	0103	7295	381	316
2	1831	8.51159993	7585	396	345
3	1794	9883	7874	410	374
4	1757	9773	8164	425	403
5	1720	9663	8454	439	432
6	1684	9553	8744	454	462
7	1647	9444	9034	469	491
8	1610	9334	9323	483	520
9	1574	9224	9613	498	549
10	8.50941537	8.51159114	1.169903	2.32512	5.91578
11	1500	9004	1.170192	527	607
12	1464	8893	0481	541	637
13	1427	8783	0770	556	666
14	1390	8673	1059	570	695
15	1353	8563	1347	584	724
16	1317	8452	1636	599	754
17	1280	8342	1925	613	783
18	1243	8232	2214	628	812
19	1207	8122	2503	642	841
20	8.50941170	8.51158011	1.172792	2.32656	5 91871
21	1133	7901	3080	671	900
22	1096	7790	3368	685	929
23	1059	7679	3655	699	959
24	1022	7569	3943	713	988
25	0985	7458	4231	727	5.92017
26	0949	7347	4519	742	047
27	0912	7237	4807	756	076
28	0875	7126	5094	770	105
29	0838	7016	5382	784	135
30	8.50940801	8.51156905	1.175670	2.32798	5.92164
31	0764	6794	5957	813	194
32	0727	6683	6244	827	223
33	0690	6572	6531	841	252
34	0653	6461	6818	855	282
35	0616	6350	7105	869	311
36	0579	6239	7392	883	341
37	0542	6128	7679	897	370
38	0505	6017	7966	911	400
39	0468	5906	8253	925	429
40	8.50940431	8.51155795	1.178540	2.32939	5.92459
41	0394	5684	8826	953	488
42	0357	5573	9112	966	518
43	0320	5461	9398	980	547
44	0283	5350	9684	994	577
45	0245	5239	9970	2.33008	606
46	0208	5127	1.180257	022	636
47	0171	5016	0543	036	665
48	0134	4905	0829	049	695
49	0097	4793	1115	063	725
50	8.50940060	8.51154682	1.181401	2.33071	5.92754
51	0023	4569	1686	091	784
52	8.50939986	4458	1971	104	813
53	9948	4346	2256	118	843
54	9911	4234	2541	132	873
55	9874	4122	2827	145	902
56	9837	4011	3112	159	932
57	9800	3900	3397	173	962
58	9762	3788	3682	186	991
59	9725	3676	3967	200	5.93021
60	8.50939688	8.51153565	1.184252	2.33213	5.93051

LATITUDE 31 DEGREES.

Latitude.	Log. A. diff. 10″ = −0.6.	Log. B. diff. 10″ = −1.9.	Log. C. diff. 10″ = +4.7.	Log. D. diff. 10″ = +0.2.	Log. E. diff. 10″ = +0.5.
° ′					
31 00	8.50939688	8.51153565	1.184252	2.33213	5.93051
1	9651	3453	4536	227	080
2	9613	3341	4820	240	110
3	9576	3228	5104	254	139
4	9538	3116	5388	267	169
5	9501	3004	5673	281	199
6	9464	2892	5957	294	229
7	9426	2780	6241	308	258
8	9389	2668	6525	321	288
9	9351	2556	6809	335	318
10	8.50939314	8.51152444	1.187093	2.33348	5.93343
11	9277	2332	7376	361	378
12	9239	2219	7660	375	407
13	9202	2107	7943	388	437
14	9164	1995	8226	401	467
15	9127	1882	8509	414	497
16	9089	1770	8793	428	527
17	9052	1658	9076	441	556
18	9014	1545	9359	454	586
19	8977	1433	9643	467	616
20	8.50938939	8.51151320	1.189926	2.33481	5.93646
21	8902	1208	1.190209	494	676
22	8864	1095	0491	507	706
23	8827	0982	0774	520	736
24	8789	0869	1056	533	765
25	8752	0757	1339	546	792
26	8714	0644	1622	559	825
27	8677	0531	1904	572	855
28	8639	0418	2187	585	885
29	8602	0306	2469	598	915
30	8.50938564	8.51150193	1.192752	2.33611	5.93945
31	8526	0080	3034	624	975
32	8489	8.51149967	3315	637	5.94005
33	8451	9854	3597	650	035
34	8413	9741	3879	663	065
35	8375	9628	4160	676	095
36	8338	9515	4442	689	125
37	8300	9402	4724	702	155
38	8262	9288	5006	715	185
39	8225	9175	5287	727	215
40	8.50938187	8.51149062	1.195569	2.33740	5.94245
41	8149	8949	5850	753	275
42	8111	8835	6130	766	306
43	8074	8722	6411	778	336
44	8036	8609	6692	791	366
45	7998	8495	7972	804	396
46	7960	8381	7253	817	426
47	7922	8268	7534	829	456
48	7885	8155	7815	842	486
49	7847	8042	8095	855	516
50	8.50937809	8.51147928	1.198376	2.33867	5.94546
51	7771	7815	8656	880	577
52	7733	7701	8936	893	607
53	7695	7587	9216	905	637
54	7657	7473	9496	918	667
55	7620	7360	9776	930	697
56	7582	7246	1.200056	943	726
57	7544	7132	0336	955	758
58	7506	7019	0616	968	788
59	7468	6905	0895	980	818
60	8.50937430	8.51146791	1.201176	2.33993	5.94848

LATITUDE 32 DEGREES.

Latitude.	Log. A. diff. 10″ = — 0.6.	Log. B. diff. 10″ = — 1.9.	Log. C. diff. 10″ = + 4.6.	Log. D. diff. 10″ = + 0.2.	Log. E. diff. 10″ = + 0.5.
° ′					
32 00	8.50937430	8.51146791	1.201176	2.33993	5.94848
1	7392	6677	1455	2.34005	879
2	7354	6563	1734	017	909
3	7316	6449	2013	030	939
4	7278	6335	2292	042	970
5	7240	6221	2572	055	5.95000
6	7202	6107	2851	067	030
7	7164	5993	3130	079	060
8	7126	5879	3409	091	091
9	7088	5765	3688	103	121
10	8.50937050	8.51145651	1.203967	2.34116	5.95151
11	7011	5536	4246	128	182
12	6973	5422	4524	141	212
13	6935	5308	4803	153	243
14	6897	5193	5081	165	273
15	6859	5079	5360	177	303
16	6821	4964	5639	189	334
17	6783	4850	5917	202	364
18	6745	4736	6196	214	395
19	6706	4621	6474	226	425
20	8.50936668	8.51144507	1.206753	2.34238	5.95455
21	6630	4392	7031	250	486
22	6592	4277	7308	262	516
23	6554	4163	7586	274	547
24	6515	4048	7863	286	577
25	6477	3933	8141	298	608
26	6439	3819	8419	310	638
27	6401	3704	8696	322	669
28	6362	3589	8974	334	699
29	6324	3475	9251	346	730
30	8.50936286	8.51143360	1.209529	2.34358	5.95760
31	6248	3245	9806	369	791
32	6209	3130	1.210083	381	822
33	6171	3015	0359	393	852
34	6133	2900	0636	405	883
35	6094	2785	0913	417	913
36	6056	2670	1190	428	944
37	6018	2555	1467	440	974
38	5979	2440	1743	452	5.96005
39	5941	2325	2020	464	036
40	8.50935903	8.51142210	1.212297	2.34476	5.96066
41	5864	2095	2573	487	097
42	5826	1979	2849	499	127
43	5787	1864	3125	511	158
44	5749	1749	3401	522	189
45	5710	1633	3677	534	219
46	5672	1518	3954	545	250
47	5633	1403	4230	557	281
48	5595	1287	4506	569	312
49	5556	1172	4782	580	342
50	8.50935518	8.51141057	1.215058	2.34592	5.96373
51	5480	0941	5333	603	404
52	5441	0826	5609	615	434
53	5403	0710	5884	626	465
54	5364	0594	6160	638	496
55	5326	0479	6435	649	527
56	5287	0363	6710	661	557
57	5249	0247	6986	672	588
58	5210	0132	7261	684	619
59	5172	0016	7537	695	650
60	8.50935133	8.51139901	1.217812	2.34707	5.96681

LATITUDE 33 DEGREES.

Latitude.	Log. A. diff. 10″ = − 0.6.	Log. B. diff. 10″ = − 1.9.	Log. C. diff. 10″ = + 4.6.	Log. D. diff. 10″ = + 0 2.	Log. E. diff. 10″ = + 0.5.
° ′					
33 00	8.50935133	8.51139901	1.217812	2.34707	5.96681
1	5094	9785	8087	718	711
2	5056	9669	8361	729	742
3	5017	9553	8636	740	773
4	4979	9437	8911	752	804
5	4940	9321	9186	763	835
6	4901	9205	9460	774	866
7	4863	9089	9735	786	897
8	4824	8973	1.220010	797	928
9	4786	8857	0284	808	958
10	8.50934747	8.51138741	1.220559	2.34820	5.96989
11	4708	8625	0833	831	5.97020
12	4669	8509	1107	842	051
13	4631	8393	1381	853	082
14	4592	8277	1655	864	113
15	4553	8160	1930	875	144
16	4514	8044	2204	886	175
17	4475	7928	2478	897	206
18	4437	7812	2752	908	237
19	4398	7695	3026	919	268
20	8.50934359	8.51137579	1.223300	2.34930	5.97299
21	4320	7463	3573	941	330
22	4281	7346	3846	952	361
23	4243	7230	4120	963	392
24	4204	7113	4393	974	423
25	4165	6997	4666	985	454
26	4126	6880	4939	996	485
27	4087	6764	5212	2.35007	516
28	4049	6647	5486	018	547
29	4010	6531	5759	029	578
30	8.50933971	8.51136414	1.226031	2.35040	5.97609
31	3932	6297	6304	051	640
32	5893	6180	6577	061	672
33	3854	6064	6850	072	703
34	3815	5947	7122	083	734
35	3776	5830	7395	094	765
36	3737	5713	7667	104	796
37	3698	5596	7940	115	827
38	3659	5480	8212	126	858
39	3620	5365	8485	137	890
40	8 50933581	8.51135246	1.228757	2.35147	5.97921
41	3542	5129	9029	158	952
42	3503	5012	9301	168	983
43	3464	4895	9573	179	5.98014
44	3425	4778	9845	190	046
45	3386	4660	1.230117	200	077
46	3347	4543	0389	211	108
47	3308	4426	0661	221	139
48	3269	4309	0933	232	170
49	3230	4192	1205	243	202
50	8.50933191	8.51134075	1.231477	2.35253	5.98233
51	3152	3958	1748	264	264
52	3113	3840	2019	274	296
53	3074	3723	2291	284	327
54	3035	3605	2562	295	358
55	2996	3488	2833	305	389
56	2956	3371	3104	316	421
57	2917	3253	3375	326	452
58	2878	3136	3647	336	483
59	2839	3019	3918	347	515
60	8.50932800	8.51132901	1.234189	2.35357	5.98546

LATITUDE 34 DEGREES.

Latitude.	Log. A. diff. 10″ = —0.7.	Log. B. diff. 10″ = -2.0.	Log. C. diff. 10″ = +4.5.	Log. D. diff. 10″ = +0.2.	Log. E. diff. 10″ = +0.5.
° ′					
34 00	8.50932800	8.51132901	1.234189	2.35357	5.98546
1	2761	2784	4460	368	578
2	2722	2666	4730	378	609
3	2682	2548	5001	388	640
4	2643	2431	5271	398	672
5	2604	2313	5542	409	703
6	2565	2195	5813	419	735
7	2526	2078	6083	429	766
8	2486	1960	6354	439	798
9	2447	1842	6624	449	829
10	8.50932408	8.51131725	1.236895	2.35460	5.98861
11	2369	1607	7165	470	892
12	2329	1489	7435	480	924
13	2290	1371	7705	490	955
14	2251	1253	7975	500	987
15	2211	1135	8245	510	5.99018
16	2172	1017	8515	520	050
17	2133	0899	8785	530	081
18	2094	0781	9055	540	113
19	2054	0664	9325	550	144
20	8.50932015	8.51130546	1.239595	2.35560	5.99176
21	1976	0427	9864	570	207
22	1936	0309	1.240134	580	239
23	1897	0191	0403	590	270
24	1857	0073	0673	600	302
25	1818	8.51129955	0942	610	334
26	1779	9836	1211	620	365
27	1739	9718	1481	630	397
28	1700	9600	1750	639	429
29	1660	9482	2020	649	460
30	8.50931621	8.51129363	1.242289	2.35659	5.99492
31	1582	9245	2558	669	524
32	1542	9127	2827	679	555
33	1503	9008	3095	688	587
34	1463	8890	3364	698	619
35	1424	8772	3633	708	651
36	1384	8653	3902	718	682
37	1345	8534	4171	727	714
38	1305	8416	4439	737	746
39	1266	8297	4708	747	777
40	8.50931226	8.51128179	1.244977	2.35757	5.99809
41	1186	8060	5245	766	841
42	1147	7942	5513	776	872
43	1107	7823	5781	785	904
44	1068	7704	6049	795	936
45	1028	7585	6317	805	968
46	0988	7467	6586	814	6.00000
47	0949	7348	6854	824	031
48	0909	7229	7122	833	063
49	0870	7111	7390	843	095
50	8.50930830	8.51126992	1.247658	2.35852	6.00127
51	0790	6873	7926	862	159
52	0751	6754	8193	871	191
53	0711	6635	8461	880	223
54	0671	6516	8728	890	254
55	0632	6397	8996	899	286
56	0592	6278	9264	909	318
57	0552	6159	9531	918	350
58	0513	6040	9799	927	382
59	0473	5921	1.250066	937	414
60	8.50930433	8.51125802	1.250334	2.35946	6.00446

LATITUDE 35 DEGREES.

Latitude.	Log. A. diff. 10″ = −0.7.	Log. B. diff. 10″ = −2.0.	Log. C. diff. 10″ = +4.4.	Log. D. diff. 10″ = +0.15.	Log. E. diff. 10″ = +0.5.
° ′					
35 00	8.50930433	8.51125802	1.250334	2.35946	6.00446
1	0394	5682	0601	956	478
2	0354	5563	0868	965	510
3	0315	5444	1135	974	542
4	0275	5325	1402	983	574
5	0235	5206	1669	993	606
6	0195	5086	1936	2.36002	638
7	0155	4967	2203	011	670
8	0116	4848	2470	020	701
9	0076	4729	2737	029	733
10	8.50930036	8.51124610	1.253004	2.36039	6.00766
11	8.50929996	4490	3270	048	798
12	9956	4371	3537	057	830
13	9916	4251	3803	066	862
14	9877	4132	4070	075	894
15	9837	4012	4336	084	926
16	9797	3893	4602	093	958
17	9757	3773	4869	102	990
18	9717	3654	5136	111	6.01022
19	9677	3534	5402	120	054
20	8.50929638	8.51123415	1.255668	2.36129	086
21	9598	3295	5934	138	118
22	9558	3175	6200	147	150
23	9518	3056	6466	156	182
24	9477	2936	6732	165	215
25	9438	2816	6997	174	247
26	9398	2696	7263	183	279
27	9358	2577	7529	192	311
28	9318	2457	7795	200	343
29	9278	2337	8061	209	376
30	8.50929238	8.51122217	1.258327	2.36218	6.01408
31	9199	2097	8592	227	440
32	9159	1977	8858	236	472
33	9119	1858	9123	244	504
34	9079	1738	9389	253	537
35	9039	1618	9654	262	569
36	8999	1498	9919	270	601
37	8959	1378	1 260185	280	634
38	8919	1258	0450	288	666
39	8879	1138	0716	297	698
40	8.50928839	8.51121018	1.260981	2.36306	6.01730
41	8799	0897	1246	314	763
42	8759	0777	1511	323	795
43	8718	0657	1775	331	827
44	8678	0537	2040	340	860
45	8638	0416	2305	349	892
46	8598	0296	2570	357	924
47	8558	0176	2835	366	957
48	8518	0056	3099	374	989
49	8478	8.51119936	3364	383	6.02022
50	8.50928438	8.51119815	1.263629	2.36391	6.02054
51	8398	9695	3893	400	086
52	8358	9574	4158	408	119
53	8317	9454	4422	417	151
54	8277	9334	4686	425	184
55	8237	9213	4950	434	216
56	8197	9093	5215	442	248
57	8157	8972	5479	450	281
58	8117	8852	5743	459	313
59	8076	8731	6007	467	346
60	8 50928036	8.51118611	1.266272	2.36476	6.02378

LATITUDE 36 DEGREES.

Latitude.	Log. A. diff. 10″ = −0.7.	Log. B. diff. 10″ = −2.0.	Log. C. diff. 10″ = +4.4.	Log. D. diff. 10″ = +0.1.	Log. E. diff. 10″ = +0.5.
° ′					
36 00	8.50928036	8.51118611	1.266272	2.36476	6.02378
1	7996	8490	6536	484	411
2	7956	8369	6800	492	443
3	7916	8249	7063	500	476
4	7876	8128	7327	509	508
5	7835	8008	7591	517	541
6	7795	7887	7855	525	573
7	7755	7766	8119	533	606
8	7715	7646	8382	542	639
9	7674	7525	8646	550	671
10	8.50927634	8 51117404	1.268910	2.36558	6.02704
11	7594	7283	9173	566	736
12	7553	7162	9437	574	769
13	7513	7041	9700	582	802
14	7473	6920	1.269963	590	834
15	7433	6800	1.270227	598	867
16	7392	6679	0490	607	899
17	7352	6558	0753	615	932
18	7312	6437	1016	623	965
19	7271	6316	1280	631	997
20	8.50927231	8.51116195	1.271543	2.36639	6.03030
21	7191	6074	1806	647	062
22	7150	5953	2069	655	095
23	7110	5832	2332	663	128
24	7069	5710	2595	671	161
25	7029	5589	2857	679	193
26	6989	5468	3120	687	226
27	6948	5347	3383	694	259
28	6908	5226	3646	702	291
29	6867	5105	3909	710	324
30	8.50926827	8.51114984	1.274172	2.36718	6.03357
31	6787	4862	4434	726	390
32	6746	4741	4697	734	423
33	6706	4620	4959	742	455
34	6665	4498	5222	749	488
35	6625	4377	5484	757	521
36	6585	4256	5746	765	554
37	6544	4134	6009	773	587
38	6504	4013	6271	780	619
39	6463	3892	6534	788	652
40	8.50926423	8.51113770	1.276796	2.36796	6.03685
41	6383	3649	7058	803	718
42	6342	3527	7320	811	751
43	6302	3406	7582	819	784
44	6261	3284	7844	826	817
45	6221	3162	8105	834	850
46	6180	3041	8367	841	883
47	6140	2919	8629	849	916
48	6099	2798	8891	357	948
49	6059	2676	9153	864	981
50	8.50926018	8.51112555	1.279415	2.36872	6.04014
51	5977	2433	9676	879	047
52	5937	2311	9938	887	080
53	5896	2190	1.280199	894	113
54	5856	2068	0460	902	146
55	5815	1946	0722	909	179
56	5774	1824	0983	916	213
57	5734	1702	1244	924	246
58	5693	1581	1505	931	279
59	5653	1459	1767	939	312
60	8.50925612	8.51111337	1.282028	2.36946	6.04345

LATITUDE 37 DEGREES.

Latitude.	Log. A. diff. 10″ = − 0.7.	Log. B. diff. 10″ = − 2.0.	Log. C. diff. 10″ = + 4.3.	Log. D. diff. 10″ = + 0.1.	Log. E. diff. 10″ = + 0.6.
° ′					
37 00	8.50925612	8.51111337	1.282028	2.36946	6.04345
1	5571	1215	2289	953	378
2	5531	1093	2550	961	411
3	5490	0971	2811	968	444
4	5449	0849	3072	975	477
5	5408	0727	3334	983	510
6	5368	0605	3595	990	543
7	5327	0483	3856	997	576
8	5286	0361	4117	2.37005	609
9	5246	0239	4378	012	642
10	8.50925205	8.51110117	1.284639	2.37019	6.04675
11	5164	8.51109995	4900	026	708
12	5124	9873	5160	034	741
13	5083	9751	5421	041	774
14	5042	9629	5681	048	808
15	5001	9506	5942	055	841
16	4961	9384	6203	062	874
17	4920	9262	6463	069	907
18	4879	9140	6724	076	940
19	4839	9018	6984	083	974
20	8.50924798	8.51108896	1.287245	2.37090	6.05007
21	4757	8773	7505	097	040
22	4716	8651	7765	104	073
23	4676	8529	8025	111	106
24	4635	8406	8285	118	140
25	4594	8284	8546	125	173
26	4553	8161	8806	132	206
27	4512	8039	9066	139	240
28	4472	7917	9326	146	273
29	4431	7794	9586	153	306
30	8.50924390	8.51107672	1.289846	2.37160	6.05340
31	4349	7549	1.290106	167	373
32	4308	7427	0365	174	406
33	4268	7304	0625	181	439
34	4227	7182	0885	188	473
35	4186	7059	1144	194	506
36	4145	6937	1404	201	539
37	4104	6814	1664	208	573
38	4064	6691	1924	215	606
39	4023	6569	2183	222	639
40	8.50923982	8.51106446	1.292443	2.37228	6.05673
41	3941	6324	2702	235	706
42	3900	6201	2962	242	740
43	3859	6078	3221	248	773
44	3818	5955	3481	255	807
45	3777	5832	3740	262	840
46	3736	5710	3999	268	874
47	3695	5587	4259	275	907
48	3654	5464	4518	282	946
49	3613	5341	4778	288	974
50	8.50923572	8.51105218	1.295037	2.37295	6 06008
51	3531	5096	5296	301	041
52	3490	4973	5555	308	075
53	3449	4850	5814	314	109
54	3408	4727	6073	321	142
55	3368	4604	6332	327	176
56	3327	4481	6591	334	209
57	3286	4358	6850	340	243
58	3245	4235	7109	347	277
59	3204	4112	7368	353	310
60	8.50923163	8.51103989	1.297627	2.37360	6.06344

LATITUDE 38 DEGREES.

Latitude.	Log. A. diff. 10″ = − 0.7.	Log. B. diff. 10″ = − 2.1.	Log. C. diff. 10″ = + 4.3.	Log. D. diff. 10″ = + 0.1.	Log. E. diff. 10″ = + 0.6.
° ′					
38 00	8.50923163	8.51103989	1.297627	2.37360	6.06344
1	3122	3866	7885	366	377
2	3081	3743	8144	373	411
3	3040	3620	8403	379	445
4	2999	3497	8661	385	478
5	2958	3374	8920	392	512
6	2916	3250	9178	398	545
7	2875	3127	9437	404	579
8	2834	3004	9695	411	613
9	2793	2881	9954	417	646
10	8.50922752	8.51102758	1.300212	2.37423	6.06680
11	2711	2635	0470	429	714
12	2670	2511	0728	436	747
13	2629	2388	0986	442	781
14	2588	2265	1244	448	815
15	2546	2141	1503	454	849
16	2505	2018	1761	460	882
17	2464	1895	2019	467	916
18	2423	1771	2277	473	950
19	2382	1648	2535	479	984
20	8.50922341	8.51101525	1.302793	2.37485	6.07018
21	2300	1401	3051	491	051
22	2259	1278	3309	497	085
23	2218	1155	3567	504	119
24	2177	1031	3825	510	153
25	2135	0908	4082	516	187
26	2094	0784	4340	522	220
27	2053	0661	4598	528	254
28	2012	0537	4856	534	288
29	1971	0414	5114	540	322
30	8.50921930	8.51100290	1.305372	2.37546	6.07356
31	1889	0167	5630	551	390
32	1847	0043	5887	557	424
33	1806	8.51099919	6145	563	457
34	1765	9796	6402	569	491
35	1724	9672	6660	575	525
36	1682	9548	6918	581	559
37	1641	9425	7175	587	593
38	1600	9301	7433	593	627
39	1558	9177	7690	598	661
40	8.50921517	8.51099054	1.307948	2.37604	6.07695
41	1476	8930	8205	610	729
42	1435	8806	8462	616	763
43	1393	8682	8719	622	797
44	1352	8559	8976	627	831
45	1311	8435	9233	633	865
46	1270	8311	9490	639	899
47	1229	8187	9747	645	933
48	1187	8064	1.310004	650	967
49	1146	7940	0260	656	6.08001
50	8.50921105	8.51097816	1.310518	2.37662	6.08035
51	1064	7692	0775	667	069
52	1022	7568	1032	673	104
53	0981	7444	1289	678	138
54	0940	7320	1546	684	172
55	0898	7196	1802	690	206
56	0857	7072	2059	695	240
57	0816	6948	2316	701	274
58	0775	6824	2573	706	308
59	0733	6700	2830	712	342
60	8.50920692	8.51096576	1.313087	2.37717	6.08377

LATITUDE 39 DEGREES.

Latitude.	Log. A. diff. 10″ = — 0.7.	Log. B. diff. 10″ = — 2.1.	Log. C. diff. 10″ = + 4.3.	Log. D. diff. 10″ = + 0.1.	Log. E. diff. 10″ = + 0.6.
° ′					
39 00	8.50920692	8.51096576	1.313087	2.37717	6.08377
1	0651	6452	3343	723	411
2	0609	6328	3600	728	445
3	0568	6204	3856	734	479
4	0526	6080	4113	739	513
5	0485	5956	4370	744	547
6	0444	5832	4626	750	582
7	0402	5707	4882	755	616
8	0361	5583	5139	761	650
9	0319	5459	5395	766	684
10	8.50920278	8.51095335	1.315652	2.37771	6.08719
11	0237	5211	5908	777	753
12	0195	5086	6164	782	787
13	0154	4962	6421	787	822
14	0112	4838	6677	793	856
15	0071	4714	6933	798	890
16	0030	4589	7189	803	924
17	8.50919988	4465	7445	808	959
18	9947	4341	7702	814	993
19	9905	4217	7958	819	6.09026
20	8.50919864	8.51094092	1.318214	2.37824	6.09062
21	9823	3968	8470	829	096
22	9781	3844	8725	834	131
23	9789	3719	8981	840	165
24	9698	3595	9237	845	199
25	9656	3470	9493	850	234
26	9615	3346	9748	855	268
27	9574	3222	1.320004	860	303
28	9532	3097	0260	865	337
29	9491	2973	0515	870	371
30	8.50919449	8.51092848	1.320771	2.37875	6.09406
31	9407	2724	1027	880	440
32	9366	2599	1282	885	475
33	9324	2475	1538	890	509
34	9283	2350	1794	895	544
35	9241	2225	2050	900	578
36	9200	2101	2305	905	613
37	9158	1976	2561	910	647
38	9117	1851	2817	915	682
39	9075	1727	3072	920	716
40	8.50919034	8.51091603	1.323328	2.37925	6.09751
41	8992	1478	3583	930	785
42	8950	1353	3839	934	820
43	8909	1229	4090	939	855
44	8867	1104	4350	944	889
45	8826	0979	4605	949	924
46	8784	0854	4860	954	958
47	8743	0730	5116	958	993
48	8701	0605	5371	963	6.10028
49	8659	0480	5627	968	062
50	8.50918618	8.51090356	1.325882	2.37973	6.10097
51	8576	0231	6137	978	131
52	8535	0106	6392	982	166
53	8493	8.51089981	6647	987	201
54	8452	9856	6902	992	236
55	8410	9731	7157	996	270
56	8368	9607	7411	2.38001	305
57	8327	9482	7666	006	340
58	8285	9357	7921	010	374
59	8244	9232	8176	015	409
60	8.50918202	8.51089107	1.328431	2.38019	6.10444

LATITUDE 40 DEGREES.

Latitude.	Log. A. diff. 10″ = −0.7.	Log. B. diff. 10″ = −2.1.	Log. C. diff. 10″ = +4.2.	Log. D. diff. 10″ = +0.1.	Log. E. diff. 10″ = +0.6.
° ′					
40 00	8.50918202	8.51089107	1.328431	2.38019	6.10444
1	8160	8982	8686	024	479
2	8119	8857	8941	029	513
3	8077	8732	9196	033	548
4	8035	8607	9451	038	583
5	7993	8482	9705	042	618
6	7952	8357	9960	047	653
7	7910	8232	1.330215	051	687
8	7868	8107	0470	056	722
9	7827	7982	0725	060	757
10	8.50917785	8.51087857	1.330980	2.38065	6.10792
11	7743	7732	1234	069	827
12	7702	7607	1489	073	861
13	7660	7482	1748	078	896
14	7618	7357	1998	082	931
15	7576	7232	2252	087	966
16	7535	7107	2507	091	6.11001
17	7493	6982	2761	095	036
18	7451	6857	3015	099	071
19	7410	6732	3270	104	106
20	8.50917368	8.51086607	1.333525	2.38108	6.11141
21	7326	6482	3779	112	176
22	7285	6356	4033	116	211
23	7243	6231	4288	121	246
24	7201	6106	4542	125	281
25	7160	5981	4796	129	316
26	7118	5855	5050	133	351
27	7076	5730	5304	137	386
28	7034	5605	5559	142	421
29	6993	5480	5813	146	456
30	8.50916951	8.51085355	1.336067	2.38150	6.11491
31	6909	5229	6321	154	526
32	6867	5104	6575	158	561
33	6826	4979	6829	162	596
34	6784	4853	7083	166	631
35	6742	4728	7337	170	666
36	6700	4603	7591	175	701
37	6658	4477	7645	179	736
38	6617	4352	8099	183	771
39	6575	4227	8353	187	806
40	8.50916533	8.51084101	1.338607	2.38191	6.11841
41	6491	3976	8861	195	876
42	6449	3850	9114	198	911
43	6408	3725	9368	202	947
44	6366	3599	9622	206	982
45	6324	3474	9875	210	6.12017
46	6282	3349	1.340129	214	052
47	6240	3223	0383	218	087
48	6199	3098	0637	222	123
49	6157	2972	0890	226	158
50	8.50916115	8.51082847	1.341144	2.38230	6.12193
51	6073	2721	1398	233	228
52	6031	2596	1651	237	263
53	5981	2470	1905	241	299
54	5948	2345	2159	245	334
55	5906	2219	2412	249	369
56	5864	2093	2666	252	405
57	5822	1968	2920	256	440
58	5780	1842	3174	260	475
59	5738	1717	3427	263	510
60	8.50915696	8.51081591	1.343681	2.38267	6.12546

LATITUDE 41 DEGREES.

Latitude.	Log. A. diff. 10″ = −0.7.	Log. B. diff. 10″ = −2.1.	Log. C. diff. 10″ = +4.2.	Log. D. diff. 10″ = +0.1.	Log. E. diff. 10″ = +0.6.
° ′					
41 00	8.50915696	8.51081591	1.343681	2.38267	6.12546
1	5655	1465	3934	271	581
2	5613	1340	4188	274	616
3	5571	1214	4441	278	652
4	5529	1089	4695	282	687
5	5487	0963	4948	285	723
6	5445	0837	5201	289	758
7	5403	0712	5455	292	793
8	5361	0586	5708	296	829
9	5319	0460	5962	300	864
10	8.50915278	8.51080335	1.346215	2.38303	6.12900
11	5236	0209	6468	307	935
12	5194	0083	6722	310	970
13	5152	8.51079958	6975	314	6.13006
14	5110	9832	7229	317	041
15	5068	9706	7482	321	077
16	5026	9580	7735	324	112
17	4984	9455	7989	327	148
18	4942	9329	8242	331	183
19	4900	9203	8496	334	219
20	8.50914858	8.51079077	1.348747	2.38338	6.13254
21	4816	8952	9000	341	290
22	4774	8826	9253	344	325
23	4732	8700	9505	348	361
24	4690	8574	9758	351	396
25	4648	8448	1.350011	354	432
26	4607	8322	0264	358	468
27	4565	8196	0517	361	503
28	4523	8070	0769	364	539
29	4481	7944	1022	367	514
30	8.50914439	8.51077819	1.351275	2.38371	6.13610
31	4397	7693	1528	374	646
32	4355	7567	1781	377	681
33	4313	7441	2034	380	717
34	4271	7315	2287	384	752
35	4229	7189	2539	387	788
36	4187	7063	2792	390	824
37	4145	6937	3045	393	860
38	4103	6811	3298	396	895
39	4061	6685	3551	399	931
40	8.50914019	8.51076559	1.353804	2.38402	6.13967
41	3977	6433	4057	405	6.14002
42	3935	6307	4309	408	038
43	3893	6181	4562	411	074
44	3851	6055	4814	414	110
45	3809	5929	5067	417	145
46	3767	5803	5320	420	181
47	3725	5677	5570	423	217
48	3683	5551	5825	426	253
49	3641	5425	6077	429	289
50	8.50913599	8.51075299	1.356333	2.38432	6.14324
51	3557	5172	6582	435	360
52	3515	5046	6835	438	396
53	3473	4920	7087	441	432
54	3431	4794	7340	443	468
55	3388	4668	7592	446	504
56	3346	4542	7844	449	540
57	3304	4416	8097	452	576
58	3262	4290	8349	455	611
59	3220	4164	8602	458	647
60	8.50913178	8.51074037	1.358854	2.38461	6.14683

LATITUDE 42 DEGREES.

Latitude.	Log. A. diff. 10″ = −0.7.	Log. B. diff. 10″ = −2.1.	Log. C. diff. 10″ = +4.2.	Log. D. diff. 10″ = +0.0.	Log. E. diff. 10″ = +0.6.
° ′					
42 00	8.50913178	8.51074037	1.358854	2.38461	6.14683
1	3136	3911	9106	464	719
2	3094	3785	9359	466	755
3	3052	3659	9611	469	791
4	3010	3533	9864	472	827
5	2968	3406	1.360116	474	863
6	2926	3260	0368	477	899
7	2884	3154	0621	480	935
8	2842	3028	0873	483	971
9	2800	2902	1126	485	6.15007
10	8.50912758	8.51072775	1.361376	2.38488	6.15043
11	2716	2649	1630	491	079
12	2674	2523	1882	493	115
13	2632	2397	2134	496	151
14	2590	2270	2386	498	187
15	2547	2144	2639	501	223
16	2505	2018	2891	504	259
17	2463	1892	3143	506	295
18	2421	1765	3395	509	331
19	2379	1639	3647	511	367
20	8.50912337	8.51071513	1.363899	2.38514	6.15404
21	2295	1387	4151	516	440
22	2253	1260	4403	518	476
23	2211	1134	4656	521	512
24	2169	1007	4907	523	548
25	2126	0881	5158	526	584
26	2084	0755	5410	528	621
27	2042	0628	5662	530	657
28	2000	0502	5914	533	693
29	1958	0376	6166	535	729
30	8.50911916	8.51070249	1.366418	2.38538	6.15765
31	1874	0123	6670	540	802
32	1832	8.51069997	6922	542	838
33	1789	9870	7174	545	874
34	1747	9744	7426	547	910
35	1705	9617	7678	549	947
36	1663	9491	7930	551	983
37	1621	9365	8182	554	6.16019
38	1579	9238	8434	556	055
39	1537	9112	8686	558	092
40	8.50911494	8.51068985	1.368938	2.38560	6.16128
41	1452	8859	9190	562	164
42	1410	8732	9442	565	201
43	1368	8606	9693	567	237
44	1326	8479	9945	569	274
45	1283	8353	1.370197	571	310
46	1241	8226	0449	573	346
47	1199	8100	0701	575	383
48	1157	7973	0952	577	419
49	1115	7847	1204	579	456
50	8.50911073	8.51067720	1.371456	2.38581	6.16492
51	1031	7594	1708	583	528
52	0988	7467	1959	585	565
53	0946	7341	2211	587	601
54	0904	7214	2462	589	638
55	0862	7088	2714	591	674
56	0820	6961	2966	593	711
57	0778	6835	3217	595	747
58	0735	6708	3469	597	784
59	0693	6581	3720	599	820
60	8.50910651	8.51066455	1.373972	2.38601	6.16857

LATITUDE 43 DEGREES.

Latitude.	Log. A. diff. 10″ = − 0.7.	Log. B. diff. 10″ = − 2.1.	Log. C. diff. 10″ = + 4.2.	Log. D. diff. 10″ = + 0.0.	Log. E. diff. 10″ = + 0.6.
° ′					
43 00	8.50910651	8.51066455	1.373973	2.38601	6.16857
1	0609	6328	4223	03	893
2	0567	6202	4475	05	930
3	0524	6075	4726	07	966
4	0482	5949	4978	08	6.17003
5	0440	5822	5230	10	040
6	0398	5695	5481	12	076
7	0356	5569	5733	14	113
8	0313	5442	5984	16	149
9	0271	5316	6236	17	186
10	8.50910229	8.51065189	1.376487	2.38619	6.17223
11	0187	5063	6739	21	259
12	0145	4936	6990	23	296
13	0102	4809	7242	24	333
14	0060	4683	7493	26	369
15	0018	4556	7745	28	406
16	8.50909976	4429	7996	29	443
17	9934	4303	8248	31	480
18	9891	4176	8499	33	516
19	9849	4050	8751	34	553
20	8.50909807	8.51063923	1.379002	2.38636	6.17590
21	9765	3796	9253	38	626
22	9723	3670	9505	39	663
23	9680	3543	9756	41	700
24	9638	3416	1.380008	42	737
25	9596	3289	0259	44	774
26	9554	3163	0510	45	810
27	9512	3036	0762	47	847
28	9469	2909	1013	48	884
29	9427	2783	1265	50	921
30	8.50909385	8.51062656	1.381516	2.38651	6.17958
31	9343	2529	1767	53	994
32	9300	2402	2019	54	6.18031
33	9258	2276	2270	55	068
34	9216	2149	2521	57	105
35	9173	2022	2773	58	142
36	9131	1895	3024	60	179
37	9089	1769	3275	61	216
38	9047	1642	3526	62	253
39	9004	1515	3778	64	290
40	8.50908962	8.51061388	1.384029	2.38665	6.18326
41	8920	1262	4280	66	363
42	8878	1135	4531	68	400
43	8835	1008	4782	69	437
44	8793	0882	5033	70	474
45	8751	0755	5285	71	511
46	8709	0628	5536	72	548
47	8666	0501	5787	74	585
48	8624	0374	6038	75	622
49	8582	0248	6289	76	659
50	8.50908540	8.51060121	1.386540	2.38677	6.18696
51	8497	8.51059994	6791	78	734
52	8455	9867	7042	79	771
53	8413	9741	7294	81	808
54	8371	9614	7545	82	845
55	8328	9487	7796	83	882
56	8286	9360	8047	84	919
57	8244	9234	8298	85	956
58	8202	9107	8550	86	993
59	8159	8980	8801	87	6.19030
60	8.50908117	8.51058853	1.389052	2.38688	6.19068

LATITUDE 44 DEGREES.

Latitude.	Log. A. diff. 10″=−0.7.	Log. B. diff. 10″=−2.1.	Log. C. diff. 10″=+4.2.	Log. D. diff. 10″=+0.0.	Log. E. diff. 10″=+0.6.
° ′					
44 00	8.50908117	8.51058853	1.389052	2.38688	6.19068
1	8075	8726	9303	89	105
2	8032	8600	9554	90	142
3	7990	8473	9805	91	179
4	7948	8346	1.390056	92	216
5	7905	8219	0308	93	254
6	7863	8092	0559	94	291
7	7821	7965	0810	95	328
8	7779	7838	1061	96	365
9	7736	7712	1312	97	403
10	8.50907694	8.51057585	1.391563	2.38698	6.19440
11	7652	7458	1814	98	477
12	7610	7331	2065	99	514
13	7567	7204	2316	2.38700	552
14	7525	7077	2567	01	589
15	7483	6951	2819	02	626
16	7441	6824	3070	02	664
17	7399	6697	3321	03	701
18	7356	6570	3572	04	738
19	7314	6443	3823	05	776
20	8.50907272	8.51056316	1.394074	2.38705	6.19813
21	7230	6190	4325	06	851
22	7187	6063	4576	07	888
23	7145	5936	4827	07	925
24	7103	5809	5078	08	963
25	7060	5682	5329	09	6.20000
26	7018	5555	5580	09	038
27	6976	5428	5831	10	075
28	6934	5301	6082	11	112
29	6891	5175	6335	11	150
30	8.50906849	8.51055048	1.396584	2.38712	6.20187
31	6807	4921	6835	12	225
32	6764	4794	7086	13	262
33	6722	4667	7337	13	300
34	6680	4540	7588	14	337
35	6637	4413	7839	14	375
36	6595	4286	8090	15	412
37	6553	4160	8341	15	450
38	6511	4033	8592	16	488
39	6468	3906	8843	16	525
40	8.50906426	8.51053779	1.399094	2.38717	6.20563
41	6384	3652	9345	17	600
42	6341	3525	9596	17	638
43	6299	3398	9847	18	676
44	6257	3271	1.400098	18	713
45	6214	3144	0348	19	751
46	6172	3018	0599	19	789
47	6130	2891	0850	19	826
48	6088	2764	1101	20	864
49	6045	2637	1352	20	902
50	8.50906003	8.51052510	1.401603	2.38720	6.20939
51	5961	2383	1854	20	977
52	5918	2256	2105	21	6.21015
53	5876	2129	2356	21	053
54	5834	2002	2607	21	090
55	5791	1875	2858	21	128
56	5749	1748	3109	21	166
57	5707	1621	3360	22	204
58	5665	1495	3611	22	241
59	5622	1369	3862	22	279
60	8.50905580	8.51051241	1.404113	2.38722	6.21317

LATITUDE 45 DEGREES.

Latitude.	Log A. diff. 10″ = −0.7.	Log B. diff. 10″ = −2.1.	Log. C. diff. 10″ = + 4.2.	Log. D. diff. 10″ = −0.0.	Log. E. diff. 10″ = + 0.6.
° ′					
45 00	8.50905580	8.51051241	1.404113	2.38722	6.21317
1	5537	1114	4364	23	355
2	5495	0987	4615	23	393
3	5453	0860	4865	23	431
4	5411	0733	5117	23	468
5	5368	0606	5368	23	506
6	5326	0480	5619	23	544
7	5284	0353	5870	23	582
8	5241	0226	6121	23	620
9	5199	0099	6372	23	658
10	8.50905157	8.51049972	1.406623	2.38723	6 21696
11	5114	9845	6874	23	734
12	5072	9718	7125	23	772
13	5030	9591	7376	23	810
14	4988	9464	7627	23	848
15	4945	9337	7878	23	886
16	4903	9211	8129	22	924
17	4861	9084	8380	22	962
18	4818	8957	8631	22	6.22000
19	4776	8830	8882	22	038
20	8.50904734	8.51048703	1.409133	2.38722	6.22076
21	4691	8576	9384	22	114
22	4649	8449	9635	22	152
23	4607	8322	9886	21	190
24	4565	8195	1.410137	21	228
25	4522	8068	0388	21	266
26	4480	7942	0639	21	304
27	4438	7815	0890	20	342
28	4395	7688	1141	20	380
29	4353	7561	1392	20	418
30	8.50904311	8.51047434	1.411642	2.38720	6.22456
31	4268	7307	1894	19	495
32	4226	7180	2145	19	533
33	4184	7053	2396	19	571
34	4142	6927	2647	18	609
35	4099	6800	2898	18	648
36	4057	6673	3149	17	686
37	4015	6546	3400	17	724
38	3972	6419	3651	16	762
39	3930	6292	3902	16	800
40	8.50903888	8.51046165	1.414153	2.38716	6.22839
41	3846	6038	4404	15	877
42	3803	5912	4655	15	915
43	3761	5785	4906	14	954
44	3719	5658	5157	14	992
45	3676	5531	5408	13	6.23030
46	3634	5404	5659	13	069
47	3592	5277	5910	12	107
48	3550	5151	6161	12	145
49	3507	5024	6412	11	183
50	8.50903465	8.51044897	1.416663	2.38710	6.23222
51	3423	4770	6914	10	260
52	3380	4643	7166	09	299
53	3338	4516	7417	08	337
54	3296	4389	7668	08	375
55	3254	4263	7919	07	414
56	3211	4136	8170	06	452
57	3169	4009	8421	06	491
58	3127	3882	8672	05	529
59	3084	3755	8923	04	567
60	8.50903042	8.51043628	1.419174	2.38704	6.23606

LATITUDE 46 DEGREES.

Latitude.	Log. A. diff. 10″ = − 0.7.	Log. B. diff. 10″ = − 2.1.	Log. C. diff. 10″ = + 4.2.	Log. D. diff. 10″ = − 0.0.	Log. E. diff. 10″ = + 0.6.
° ′					
46 00	8.50903042	8.51043628	1.419174	2.38704	6.23606
1	3000	3501	9426	03	644
2	2958	3375	9677	02	683
3	2915	3248	9928	01	722
4	2873	3121	1.420179	00	760
5	2831	2994	0430	2.38699	799
6	2798	2867	0681	99	837
7	2746	2741	0933	98	876
8	2704	2614	1184	97	914
9	2662	2487	1435	96	953
10	8.50902619	8.51042360	1.421686	2.38695	6.23991
11	2577	2233	1937	94	6.24030
12	2535	2106	2188	93	069
13	2493	1980	2440	92	107
14	2450	1853	2690	91	146
15	2408	1726	2942	90	185
16	2366	1599	3193	89	223
17	2324	1472	3444	88	262
18	2281	1346	3696	87	301
19	2239	1219	3947	86	340
20	8.50902197	8.51041092	1.424198	2.38685	6.24378
21	2154	0965	4449	84	417
22	2112	0838	4701	83	456
23	2070	0712	4952	82	495
24	2028	0585	5203	81	533
25	1985	0458	5455	80	572
26	1943	0331	5706	79	611
27	1901	0205	5957	78	650
28	1859	0078	6208	76	688
29	1816	8.51039951	6460	75	727
30	8.50901774	8.51039825	1.426711	2.38674	6.24766
31	1732	9698	6962	73	805
32	1690	9571	7214	72	844
33	1647	9444	7465	70	883
34	1605	9318	7716	69	921
35	1563	9191	7968	68	960
36	1521	9064	8219	67	6.24999
37	1479	8937	8470	65	6.25038
38	1436	8811	8722	64	077
39	1394	8684	8973	63	116
40	8.50901352	8.51038557	1.429225	2.38661	6.25155
41	1310	8431	9476	60	194
42	1267	8304	9727	59	233
43	1225	8177	9979	57	272
44	1183	8050	1.430230	56	311
45	1141	7924	0482	54	350
46	1098	7797	0733	53	389
47	1056	7670	0985	52	428
48	1014	7544	1236	50	467
49	0972	7417	1487	49	506
50	8.50900929	8.51037290	1.431739	2.38647	6.25545
51	0887	7163	1990	46	584
52	0845	7037	2242	44	623
53	0803	6910	2493	43	662
54	0761	6783	2745	41	701
55	0718	6657	2997	39	740
56	0676	6530	3248	38	780
57	0634	6403	3500	36	819
58	0592	6277	3751	35	858
59	0549	6150	4003	33	897
60	8.50900507	8.51036023	1.434255	2.38632	6.25936

LATITUDE 47 DEGREES.

Latitude.	Log. A. diff. 10″=−0.7.	Log. B. diff. 10″=−2.1.	Log. C. diff. 10″=+4.2.	Log. D. diff. 10″=−0.0.	Log. E. diff. 10″=+0.6.
° ′					
47 00	8.50900507	8.51036023	1.434235	2.38632	6.25936
1	0465	5897	4506	30	975
2	0423	5770	4758	28	6.26015
3	0381	5644	5009	26	054
4	0338	5517	5261	25	093
5	0296	5390	5513	23	132
6	0254	5264	5764	21	172
7	0212	5137	6016	20	211
	0170	5011	6268	18	250
9	0127	4884	6519	16	289
10	8.50900085	8.51034757	1.436771	2.38615	6.26329
11	0043	4631	7023	13	368
12	0001	4504	7274	11	407
13	8.50899959	4378	7526	09	447
14	9917	4251	7778	07	486
15	9874	4125	8030	05	526
16	9832	3998	8281	03	565
17	9790	3872	8533	02	604
18	9748	3745	8785	00	644
19	9706	3619	9037	2.38598	683
20	8.50899663	8.51033492	1.439288	2.38596	6.26722
21	9621	3366	9540	94	762
22	9579	3239	9792	92	801
23	9537	3113	1.440044	90	841
24	9495	2986	0296	88	880
25	9453	2860	0548	86	920
26	9410	2733	0800	84	959
27	9368	2607	1051	82	999
28	9326	2480	1303	80	6.27038
29	9284	2354	1555	78	078
30	8.50899242	8.51032227	1.441807	2.38576	6.27117
31	9200	2101	2059	574	157
32	9158	1974	2311	572	196
33	9115	1848	2563	569	236
34	9073	1722	2815	567	276
35	9031	1595	3067	565	315
36	8989	1469	3319	563	355
37	8947	1342	3571	561	394
38	8905	1216	3823	559	434
39	8863	1090	4075	556	474
40	8.50898820	8.51030963	1.444327	2.38554	6.27513
41	8778	0837	4579	552	553
42	8736	0710	4831	550	593
43	8694	0584	5084	547	632
44	8652	0458	5336	545	672
45	8610	0331	5588	543	712
46	8568	0205	5840	540	752
47	8526	0079	6092	538	791
48	8483	8.51029952	6344	536	831
49	8441	9826	6597	534	871
50	8.50898399	8.51029700	1.446849	2.38531	6.27911
51	8357	9573	7101	529	950
52	8315	9447	7353	526	990
53	8273	9321	7606	524	6.28030
54	8231	9194	7858	521	070
55	8189	9068	8110	519	110
56	8147	8942	8362	517	150
57	8105	8816	8615	514	190
58	8062	8689	8867	512	229
59	8020	8563	9119	509	269
60	8.50897978	8.51028437	1.449372	2.38507	6.28309

LATITUDE 48 DEGREES.

Latitude.	Log. A. diff. 10″ = — 0.7.	Log. B. diff. 10″ = — 2.1.	Log. C. diff. 10″ = + 4.2.	Log. D. diff. 10″ = — 0.0.	Log. E. diff. 10″ = + 0.7.
° ′					
48 00	8.50897978	8.51028437	1.449372	2 38507	6.28309
1	7936	8311	9624	504	349
2	7894	8184	9877	502	389
3	7852	8058	1.450129	499	429
4	7810	7932	0381	496	469
5	7768	7806	0634	494	509
6	7726	7680	0886	491	549
7	7684	7554	1139	488	589
8	7642	7427	1391	486	629
9	7600	7301	1644	483	669
10	8.50897558	8.51027175	1.451896	2.38481	6.28709
11	7516	7049	2149	478	749
12	7474	6923	2401	475	789
13	7432	6796	2654	472	829
14	7389	6670	2907	470	869
15	7347	6544	3159	467	909
16	7305	6418	3412	464	950
17	7263	6292	3664	461	990
18	7221	6166	3917	459	6.29030
19	7179	6039	4170	456	070
20	8.50897137	8.51025913	1.454422	2.38453	6.29110
21	7095	5787	4675	450	150
22	7053	5661	4928	447	190
23	7011	5535	5181	444	231
24	6969	5409	5433	442	271
25	6927	5283	5686	439	311
26	6885	5157	5939	436	351
27	6843	5031	6192	433	392
28	6801	4905	6445	430	432
29	6759	4779	6697	427	472
30	8.50896717	8.51024653	1.456950	2.38424	6.29512
31	6675	4527	7203	421	553
32	6633	4401	7456	418	593
33	6591	4275	7709	415	633
34	6549	4149	7962	412	674
35	6507	4023	8215	409	714
36	6465	3897	8468	406	754
37	6423	3771	8721	403	795
38	6381	3645	8974	400	835
39	6339	8519	9227	397	875
40	8.50896297	8.51023393	1.459480	2.38394	6.29916
41	6255	3267	9733	390	956
42	6213	3141	9986	387	997
43	6171	3016	1.460239	384	6.30037
44	6129	2890	0493	381	078
45	6087	2764	0746	378	118
46	6045	2638	0999	374	159
47	6003	2512	1252	371	199
48	5961	2386	1505	368	240
49	5919	2260	1758	365	280
50	8.50895877	8.51022134	1.462011	2.38362	6.30321
51	5836	2009	2265	358	361
52	5794	1883	2518	355	402
53	5752	1757	2772	352	443
54	5710	1631	3025	348	483
55	5668	1506	3278	345	524
56	5626	1380	3532	342	564
57	5584	1254	3785	338	605
58	5542	1128	4038	335	646
59	5500	1003	4292	331	686
60	8.50895458	8.51020877	1.464545	2.38328	6.30727

LATITUDE 49 DEGREES.

Latitude.	Log. A. diff. 10″ = − 0.7. *	Log. B. diff. 10″ = − 2.1. *	Log. C. diff. 10″ = + 4.2. *	Log. D. diff. 10″ = − 0.1. *	Log. E. diff. 10″ = + 0.7. *
° ′					
49 00	8.50895458	8.51020877	1.464545	2.38328	6.30727
1	5416	0751	4799	325	768
2	5375	0625	5052	321	808
3	5333	0500	5306	318	849
4	5291	0374	5559	314	890
5	5249	0248	5813	311	930
6	5207	0123	6067	307	971
7	5165	8.51019997	6320	304	6.31012
8	5123	9871	6574	300	053
9	5081	9746	6827	297	093
10	8.50895039	8.51019620	1.467081	2.38293	6.31134
11	4998	9495	7335	289	175
12	4956	9369	7589	286	216
13	4914	9243	7842	282	257
14	4872	9118	8096	278	298
15	4830	8992	8350	275	338
16	4788	8867	8604	271	379
17	4746	8741	8858	267	420
18	4705	8615	9111	264	461
19	4663	8490	9365	260	502
20	8.50894621	8.51018364	1.469619	2.38256	6.31543
21	4579	8239	9873	253	584
22	4537	8113	1.470127	249	625
23	4495	7988	0381	245	666
24	4454	7862	0635	241	707
25	4412	7737	0889	238	748
26	4370	7612	1143	234	789
27	4328	7486	1397	230	830
28	4286	7361	1651	226	871
29	4245	7235	1905	222	912
30	8.50894203	8.51017110	1.472159	2.38219	6.31953
31	4161	6984	2413	215	994
32	4119	6859	2668	211	6.32035
33	4077	6734	2922	207	077
34	4035	6608	3176	203	118
35	3994	6483	3430	199	159
36	3952	6358	3685	195	200
37	3910	6232	3939	191	241
38	3868	6107	4193	187	282
39	3827	5982	4447	183	324
40	8.50893785	8.51015856	1.474702	2.38179	6.32365
41	3743	5731	4956	175	406
42	3701	5606	5211	171	447
43	3660	5481	5465	167	488
44	3618	5355	5720	163	530
45	3576	5230	5974	159	571
46	3534	5105	6229	154	612
47	3493	4980	6483	150	653
48	3451	4854	6738	146	695
49	3409	4729	6992	142	736
50	8.50893367	8.51014604	1.477247	2.38138	6.32777
51	3326	4479	7502	134	819
52	3284	4354	7756	130	860
53	3242	4228	8011	125	901
54	3200	4103	8266	121	943
55	3159	3978	8521	117	984
56	3117	3853	8775	113	6.33026
57	3075	3728	9030	108	067
58	3034	3603	9285	104	108
59	2992	3488	9540	100	150
60	8.50892950	8.51013353	1.479794	2.38095	6.33191

* Throughout the tables the differences for 10″ in the values of logs A, B, C, D, E refer to one place of decimals less than is given in the tables.

APPENDIX No. 37.

Account of Cauchy's interpolation formula.

(Prepared by Charles A. Schott, Assistant Coast Survey.)

In many physical investigations the application of the method of least squares becomes laborious whenever a great number of complicated conditional equations are to be treated, and it is therefore occasionally convenient to make use of a sufficiently rigorous method, which, hardly inferior to that of least squares, has the advantage of leading, in less time and with less labor, to a result of an accuracy commensurate with that of the observations themselves. Such a method has been devised by Cauchy, and it is here proposed to give, for convenience of reference, an account of Cauchy's interpolation formula. It is a free translation from Moigno's account in his edition of Cauchy's differential calculus,* and has been illustrated with an example.

Let y represent a function of x capable of being developed in a converging series, arranged according to ascending or descending powers of x, or according to sines or cosines of multiple arcs of x, or, in general, according to any other functions of x which may be represented by

$$\varphi x = u \qquad \chi x = v \qquad \psi x = w \qquad \ldots\ldots$$
$$y = a u + b v + c w + \cdots \qquad \ldots\ldots \quad (1)$$

$a\ b\ c \ldots$ being coefficients to be determined. It will be necessary to know, first, how many terms in the second member of equation (1) have to be included to obtain for y a value sufficiently close so as not to deviate from the truth by a quantity greater than is commensurate with the errors of observation themselves; and, secondly, to express numerically the coefficients of the expression adopted. For the solution of the problem we have given a sufficient number of values of y represented by $y_1\, y_2\, y_3 \ldots\ldots y_n$ corresponding to the same number of values of x expressed by $x_1\, x_2\, x_3 \ldots\, x_n$ and corresponding to an equal number of values for the functions $u\ v\ w \ldots\ldots$ represented by $u_1\, u_2\, u_3 \ldots\ldots u_n$ for the function u, and by $v_1\, v_2\, v_3 \ldots\ldots v_n$ for the function v, and by $w_1\, w_2\, w_3 \ldots\ldots w_n$ for the function w, &c., &c., we have therefore the following conditional linear equations:

$$y_1 = a\,u_1 + b\,v_1 + c\,w_1 + \ldots\ldots$$
$$y_2 = a\,u_2 + b\,v_2 + c\,w_2 + \ldots\ldots$$
$$\text{etc.}$$
$$y_n = a\,u_n + b\,v_n + c\,w_n + \ldots\ldots$$

comprised in the general form—

$$y_i = a\,u_i + b\,v_i + c\,w_i + \ldots\ldots$$

where i designates any integer number 1, 2, 3....n. For a first approximation we can neglect the coefficients $b\ c \ldots\ldots$ or we reduce the series to its first term, then the general approximate value of y will be $y = a\,u$, for which we have the systems of equations—

$$y_1 = a\,u_1 \qquad y_2 = a\,u_2 \ \ldots\ \ y_n = a\,u_n \qquad \ldots\ldots\ldots\ldots \quad (2)$$

The y's being given by observation and the terms beyond the first being neglected, these equations will produce different values for a, and require therefore to be combined in such a manner as to render the bad effect on the value of this coefficient, produced by errors in the amount of $y_1\, y_2 \ldots\ldots y_n$, the least possible. The different combinations to that effect, which can be made with reference to the value of a and the equations (2) are comprised in the general form:

$$a = \frac{k_1\,y_1 + k_2\,y_2 + \ldots\ldots\ k_n\,y_n}{k_1\,u_1 + k_2\,u_2 + \ldots\ldots\ k_n\,u_n}$$

* Leçons de calcul différentiel de M. A. L. Cauchy, par M. l'Abbé Moigno. Paris, 1840.

obtained by multiplication of each term by factors $k_1 k_2 \dots k_n$ and by subsequent summation. This value of a will not vary if we change all the factors in the same ratio and the greatest one (irrespective of sign) may always be considered as reduced to unity. If $\varepsilon_1 \varepsilon_2 \dots \varepsilon_n$ represent the errors committed respectively in the observations $y_1 y_2 \dots y_n$, the preceding formula will furnish a value for a differing from the true value by

$$\frac{k_1 \varepsilon_1 + k_2 \varepsilon_2 \dots + k_n \varepsilon_n}{k_1 u_1 + k_2 u_2 \dots + k_n u_n}$$

and we have to select such values for $k_1 k_2 \dots k_n$ as will make this difference as small as possible.

Let Σu_i be the sum of the numerical values of the polynome $\pm u_1 \pm u_2 \dots \pm u_n$, each term having been rendered positive, and supposing each value u_i replaced by its corresponding value ε_i we will call this latter sum $\Sigma \varepsilon_i$.

If each coefficient $k_1 k_2 \dots k_n$ is reduced to either $+1$ or -1, and if we select the sign in such a manner as to make the terms of the denominator of the above fraction all positive, it will assume the value $\frac{\Sigma \varepsilon_i}{\Sigma u_i}$ which approximates nearest to the value $\frac{E}{\Sigma u_i}$, where E equals the sum of the numerical values of ε_i.

If, on the other hand, we were to attribute unequal values to $k_1 k_2 \dots k_n$ of which the greatest (irrespective of sign) would be unity, the denominator would assume a value evidently inferior to Σu_i whilst the numerical value of the numerator might rise as high as the limit E, (in this case $\varepsilon_1 \varepsilon_2 \dots \varepsilon_n$ would all be zero excepting that ε which is multiplied by the unit;) it follows, then, that the greatest error in the value of a, to be apprehended, will be as small as possible by assuming generally $k_i = \pm 1$, choosing the signs so as to make all terms positive in the expression $k_1 u_1 + k_2 u_2 + \dots k_n u_n$. We then have—

$$a = \frac{\Sigma y_i}{\Sigma u_i} \qquad y = \frac{u}{\Sigma u_i} \Sigma y_i. \text{ for which we can write } y = a \Sigma y_i.$$

For $u = 1$ the equation $y = au$ is reduced to $y = a$ and $a = \frac{1}{u}$ or $y = \frac{\Sigma y_i}{u}$; the arithmetical mean gives, therefore, the nearest approximation to the value y.

Let Δy be its correction, then $y = a \Sigma y_i + \Delta y$,
and in a similar manner—

$$v = a \Sigma v_i + \Delta v \qquad w = a \Sigma w_i + \Delta w, \text{ etc., etc.}$$

From the formula $y_i = au_i + bv_i + cw_i + \cdots$ we obtain—

$$\Sigma y_i = a \Sigma u_i + b \Sigma v_i + c \Sigma w_i + \cdots$$

multiplying by a, and subtracting from $y = au + bv + cw + \cdots$
we find $\Delta y = b \Delta v + c \Delta w + \dots\dots$ (3)

Let $a_i \Delta y_i \Delta v_i \Delta w_i$ represent the corresponding values of $a \Delta y \Delta v \Delta w$ after x is replaced by x_i, then if the values $\Delta y_1 \Delta y_2 \cdots \Delta y_n$ are very small, and comparable to the errors of observation, no second approximation need be made, and y becomes $= a \Sigma y_i$. On the contrary, if this is not the case we obtain a new approximation by operating on formula (3) in the same manner as we have done on formula (1.)

Premising the above, let $\Sigma^1 \Delta v_i$ be the sum of the numerical values of Δv_i and $\Sigma^1 \Delta y_i$, $\Sigma^1 \Delta w_i$, etc., the sums into which $\Sigma^1 \Delta v_i$ is changed, when each Δv_i, is replaced by its corresponding value of Δy_i or of Δw_i, etc., and let $\beta = \frac{\Delta v}{\Sigma^1 \Delta v_i}$ then if the 3d and following terms in equation (1) can be neglected—

$$\Delta y = \beta \Sigma^1 \Delta y_i \text{ as an approximation, or strictly}$$
$$\Delta y = \beta \Sigma^1 \Delta y_i + \Delta^2 y.$$

Again, let $\Delta w = \beta \Sigma^1 \Delta w_i + \Delta^2 w$, etc., etc., then by formula (3)

$$\Delta y_i = b \Delta v_i + c \Delta w_i + \cdots \text{ also } \Sigma^1 \Delta y_i = b \Sigma^1 \Delta v_i + c \Sigma^1 \Delta w_i + \cdots\cdots$$

multiplying the last expression by β, and subtracting it from the expression for $\Delta\, y$, we find

$$\Delta^2\, y = c\, \Delta^2 w + \cdots\cdots$$

Now designate by $\beta_1\, \Delta^2\, y_1\, \Delta^2\, w_1\, \cdots\cdots$ the values of $\beta\, \Delta^2\, y\, \Delta^2\, w$, when x is replaced by x_1, then if the values of $\Delta^2\, y_1\, \Delta^2\, y_2 \cdots\cdots \Delta^2\, y_n$ are very small and comparable with the errors of observation we need no further approximation, and may be satisfied with $\Delta\, y = \beta\, \Sigma^1\, \Delta\, y_1$; if the contrary should be the case, it suffices for a third approximation to operate on the formula for $\Delta^2 y$ in the same manner as followed in formula (1.) This process, as developed above; when continued, leads to the following rule:

If in the converging series

$y = au + bv + cw + \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$ (I)

$u\ v\ w \cdots\cdots$ represent given functions of the same variable, and we know n particular values of y corresponding to n particular values of $x_1\ x_2 \cdots\cdots x_n$, and if we designate by $y_1\ u_1\ v_1\ w_1 \cdots\cdots$ the values of $y\ u\ v\ w \cdots\cdots$ when x is replaced by x_1, then for a first approximation, by means of the formula $u = a\, \Sigma\, u_1 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$ (II)

We find $y = a\, \Sigma\, y_1 + \Delta\, y \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$ (III)

Now, if the particular values of $\Delta\, y$ or $\Delta\, y_1\, \Delta\, y_2 \cdots\cdots \Delta\, y_n$ are of the same order of magnitude as the errors of observation, we need not proceed further; in the contrary case, we find β by means of the formulæ $v = a\, \Sigma\, v_1 + \Delta\, v$, $\quad \Delta\, v = \beta\, \Sigma^1\, \Delta\, v_1 \cdots\cdots\cdots\cdots\cdots\cdots$ (IV)

$\Sigma^1\, \Delta\, v_1$ being the sum of the numerical values of $\Delta\, v_1$ also find the differences of the second order by the formula $\Delta\, y = \beta\, \Sigma^1\, \Delta\, y + \Delta^2\, y \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$ (V)

Now, if the particular values of $\Delta^2\, y_1\, \Delta^2\, y_2 \cdots\cdots \Delta^2\, y_n$ are of the same order as the errors of observation y is sufficiently represented by $a\, \Sigma\, y_1 + \beta\, \Sigma^1\, \Delta\, y_1$; in the contrary case proceed to find γ by the formulæ—

$w = a\, \Sigma\, w_1 + \Delta\, w,\ \Delta\, w = \beta\, \Sigma^1\, \Delta\, w_1 + \Delta^2 w,\ \Delta^2\, w = \gamma\, \Sigma^{11}\, \Delta^2 w_1 \cdots\cdots\cdots\cdots\cdots\cdots$ (VI)

Where $\Sigma^{11}\, \Delta^2\, w_1$ equals the sum of the numerical values of $\Delta^2\, w_1$; next find the difference of the third order $\Delta^2\, y = \gamma\, \Sigma^{11}\, \Delta^2\, y_1 + \Delta^3\, y \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$ (VII)

Finally, supposing the co-efficients $a\, \beta\, \gamma \cdots$ to be known we have next to compute the differences of the several orders represented by $\Delta y\ \Delta^2 y\ \Delta^3 y \cdots\cdots$ or rather their particular values corresponding to the values $x_1\ x_2 \cdots\cdots x_n$ of the variable, until we arrive at a value where the differences are of the same order of magnitude as the errors of the observations themselves, and if we call m the number of preserved terms, the problem of interpolation is solved by the formula—

$$y = a\, \Sigma\, y_1 + \beta\, \Sigma^1\, \Delta\, y_1 + \gamma\, \Sigma^{11}\, \Delta^2\, y_1 + \cdots\cdots$$

continued to the term involving $\Delta^{m-1} y_1$.

From the preceding we deduce—

$$\Sigma\, a_1 = 1\quad \Sigma\, \beta_1 = 0\quad \Sigma^1\, \beta_1 = 1\quad \Sigma\, \gamma_1 = 0\quad \Sigma^1\, \gamma_1 = 0\quad \Sigma^{11}\, \gamma_1 = 1, \text{ etc.}$$

$$\text{Also } \Sigma\, \Delta\, v_1 = 0\quad \Sigma\, \Delta\, w_1 = 0\quad \Sigma\, \Delta^2\, w_1 = 0\quad \Sigma^1\, \Delta^2\, w_1 = 0, \text{ etc.};$$

and $\Sigma\, \Delta\, y_1 = 0\quad \Sigma\, \Delta^2\, y_1 = 0\quad \Sigma^1\, \Delta^2\, y_1 = 0\quad \Sigma\, \Delta^3\, y_1 = 0\quad \Sigma^1\, \Delta^3\, y_1 = 0\quad \Sigma^{11}\, \Delta^3\, y_1 = 0$, which expressions must be satisfied by the values of $a\, \beta\, \gamma \cdots\cdots$ as well as by the differences of the different orders of $u,\ v,\ w \cdots\cdots y$, and are a useful auxiliary to guard against the commission of errors of computation.

In conclusion, the advantages of these formulæ of interpolation may be stated as follows:

1. They apply to the development of a series, no matter what the law may be by which the different terms are established, and whatever may be the increments (equal or not) of the independent variable.

2. The formulæ are of easy application, particularly if logarithms are used in computing the ratios $a\, \beta\, \gamma \cdots\cdots$

3. The successive approximations are generally obtained with more facility the further we proceed.

4. The process involves at once all the numbers furnished by observation, and hence admits of a very large number of experiments.

5. They possess the advantage that for each new approximation the successive values for a, b, $c \cdots$ are always those for which we need apprehend but the smallest possible error.

6. They indicate of themselves the moment when the calculation has arrived at a sufficient approximation commensurate with the accuracy of the observations.

7. The numerical process is checked in its intermediate steps.

The following example has been selected from another part of this report.—(See the discussion of the apparent connection between the angular movement of the horizontal magnetic needle and the variation in the moon's hour angle, as observed and deduced from the observations at Girard College, Philadelphia.) From that discussion the following numerical values have been obtained, they depend on not less than 21,644 observations taken in the years 1840 to 1845.

Moon's hour angle.	Deflection from normal declination.	Moon's hour angle.	Deflection from normal declination.
	′		′
0	+0.19	12	+0.29
1	+0.17	13	+0.19
2	+0.05	14	+0.13
3	+0.04	15	+0.06
4	—0.10	16	—0.10
5	—0.14	17	—0.18
6	—0.19	18	—0.26
7	—0.14	19	—0.19
8	—0.15	20	—0.12
9	+0.01	21	+0.01
10	+0.10	22	+0.04
11	+0.19	23	+0.12

These numbers may be represented by the periodic form—

$$\Delta_{☾} = \mathrm{A} + \mathrm{B}\sin.(\theta + \mathrm{C}) + \mathrm{D}\sin.(2\,\theta + \mathrm{E}) + \cdots\cdots\cdots$$

where—

$\Delta_{☾}$ = the lunar diurnal variation of the magnetic declination. + west, — east deflection.

θ the moon's hour angle reckoned from the upper culmination.

A, B, C, D, E$\cdots\cdots$ constants to be determined.

An examination of the signs of the numerical values of $\Delta_{☾}$ shows that the term depending on $2\,\theta$ is the most prominent; hence D should be determined before B and the periodic terms following it.

Putting B sin. C $= p$, B cos. C $= q$, D sin E $= r$, and D cos E $= s$,

the above expression becomes:

$$\Delta_{☾} = \mathrm{A} + r\cos.2\,\theta + s\sin.2\,\theta + p\cos.\theta + q\sin.\theta + \cdots\cdots$$

In the present case the value of A is simply the arithmetical mean of the 24 numerical values = + 0′.001, which on account of its smallness may be neglected; the reduction of the observations stand as follows:

$\Delta_{☾}$	Cos. 2 θ. (r.)	Sin. 2 θ. (s.)	Cos. θ. (p.)	Sin. θ. (q.)	$\Delta'_{☾}$	$\Delta''_{☾}$
′					′	′
+ 0.19	+ 1.00	0.00	+ 1.00	0 00	− 0.01	+ 0.01
+ 0.17	+ 0.87	+ 0.50	+ 0.97	+ 0.26	− 0.01	+ 0.01
+ 0.05	+ 0.50	+ 0.87	+ 0.87	+ 0.50	− 0.06	− 0.04
+ 0.04	0.00	+ 1.00	+ 0.71	+ 0.71	+ 0.02	+ 0.03
− 0.10	− 0.50	+ 0.87	+ 0.50	+ 0.87	− 0 01	− 0.01
− 0.14	− 0.87	+ 0.50	+ 0.26	+ 0.97	+ 0.02	+ 0.02
− 0.19	− 1.00	0.00	0.00	+ 1.00	+ 0.01	0.00
− 0.14	− 0.87	− 0.50	− 0.26	+ 0.97	+ 0.04	+ 0.02
− 0.15	− 0.50	− 0.87	− 0.50	+ 0.87	− 0.04	− 0.06
+ 0.01	0.00	− 1.00	− 0.71	+ 0.71	+ 0.03	0.00
+ 0.10	+ 0.50	− 0.87	− 0.87	+ 0.50	+ 0.01	− 0.01
+ 0.19	+ 0.87	− 0.50	− 0.97	+ 0.26	+ 0.03	+ 0.01
+ 0 29	+ 1.00	0.00	− 1.00	0 00	+ 0.09	+ 0.07
+ 0.19	+ 0.87	+ 0.50	− 0.97	− 0.26	+ 0.01	− 0.01
+ 0.13	+ 0.50	+ 0.87	− 0.87	− 0.50	+ 0.02	0 00
+ 0.06	0.00	+ 1.00	− 0.71	− 0.71	+ 0.04	+ 0.03
− 0.10	− 0.50	+ 0 87	− 0.50	− 0.87	− 0.01	− 0.01
− 0.18	− 0.87	+ 0.50	− 0.26	− 0.97	− 0.02	− 0.02
− 0.26	− 1.00	0.00	0.00	− 1.00	− 0.06	− 0.05
− 0.19	− 0.87	− 0.50	+ 0.26	− 0.97	− 0.01	+ 0.01
− 0.12	− 0.50	− 0.87	+ 0.50	− 0.87	− 0.01	+ 0.01
+ 0.01	0.00	− 1.00	+ 0.71	− 0.71	+ 0.03	+ 0.06
+ 0.04	+ 0.50	− 0.87	+ 0.87	− 0.50	− 0.05	− 0.03
+ 0.12	+ 0.87	− 0.50	+ 0.97	− 0.26	− 0.04	− 0.02
+ 3.04	+14.96	0	0	0		
+ 0.25	0	+14.96	0	0		

Applying the values r cos. 2 θ, and s sin. 2 θ, we find the new residuals, $\Delta'_{☾}$.

Cos. θ.	Sin. θ.	$\Delta'_{☾}$
+15.24	0	− 0.33
0	+15.24	+ 0.14

$r = \frac{8.04}{14.96} = + 0.203.$

$s = \frac{0\ 25}{14.95} = + 0.017.$

$p = \frac{-0.33}{15.24} = - 0.022.$

$q = \frac{0.14}{15.24} = + 0.09.$

Applying the values p cos. θ and q sin. θ, we find the residuals $\Delta''_{☾}$, which show that no further approximation is needed. Therefore the expression becomes:

$$\Delta_{☾} = + 0'.001 + 0'.203 \cos. 2\,\theta + 0'.017 \sin. 2\,\theta - 0'.022 \cos. \theta + 0'.009 \sin. \theta.$$

Which may be transferred into—

$$\Delta_{☾} = + 0'.001 + 0'.024 \sin. (\theta + 292^\circ) + 0'.204 \sin. (2\,\theta + 85^\circ.)$$

By application of the method of least squares we found—

$$\Delta_{☾} = + 0'.001 + 0'.029 \sin. (\theta + 295^\circ) + 0'.207 \sin. (2\,\theta + 85^\circ.)$$

These expressions are practically identical. The sum of the remaining errors irrespective of sign is by Cauchy's method 0.54, and by the method of least squares = 0.55, the sum of the squares of the remaining errors is by Cauchy's method 0.0214, and by the method of least squares = 0.0211.

APPENDIX No. 38.

Table showing the height in feet corresponding to a given angle of elevation and a given distance in metres, for use in the construction of contour lines by the plane-table. Prepared by Charles A. Schott, Assistant United States Coast Survey.

Angle.	METRES.																	
	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
′	*Feet.*	*Feet*	*Feet.*	*Feet.*	*Feet.*	*Feet*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	0.3	0.4	0.6	0.6	0.8	0.9	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.8
2	0.6	0.8	1.0	1.2	1.5	1.7	1.9	2.1	2.4	2.6	2.9	3.1	3.4	3.7	3.9	4.2	4.5	4.7
3	0.9	1.2	1.5	1.8	2.2	2.5	2.8	3.1	3.4	3.8	4.2	4.4	4.8	5.3	5.6	5.9	6.3	6.6
4	1.2	1.5	2.0	2.4	2.8	3.2	3.6	4.1	4.5	4.9	5.4	5.8	6.3	6.8	7.2	7.6	8.1	8.6
5	1.5	1.9	2.4	2.9	3.5	4.0	4.5	5.0	5.5	6.1	6.6	7.1	7.7	8.3	8.8	9.4	9.9	10.5
6	1.8	2.3	2.9	3.5	4.2	4.8	5.3	5.9	6.6	7.2	7.9	8.5	9.1	9.8	10.4	11.1	11.7	12.4
7	2.1	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.6	8.4	9.1	9.8	10.6	11.4	12.1	12.8	13.5	14.3
8	2.4	3.1	3.9	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.1	12.0	12.9	13.7	14.5	15.3	16.2
9	2.7	3.5	4.4	5.2	6.2	7.0	7.9	8.8	9.7	10.7	11.6	12.5	13.4	14.4	15.3	16.2	17.2	18.1
10	2.9	3.8	4.9	5.8	6.8	7.8	8.8	9.8	10.8	11.8	12.8	13.8	14.9	15.9	16.9	17.9	19.0	20.0
11	3.2	4.2	5.3	6.4	7.5	8.6	9.6	10.7	11.8	13.0	14.1	15.1	16.3	17.5	18.6	19.7	20.8	21.9
12	3.5	4.6	5.8	6.9	8.2	9.3	10.5	11.7	12.9	14.1	15.3	16.5	17.7	19.0	20.2	21.4	22.6	23.8
13	3.8	5.0	6.3	7.5	8.8	10.1	11.4	12.6	13.9	15.2	16.6	17.8	19.2	20.5	21.8	23.1	24.4	25.7
14	4.1	5.4	6.8	8.1	9.5	10.9	12.2	13.6	15.0	16.4	17.8	19.1	20.6	22.0	23.4	24.8	26.2	27.6
15	4.4	5.7	7.2	8.6	10.2	11.6	13.1	14.5	16.0	17.5	19.0	20.5	22.0	23.6	25.0	26.5	28.0	29.5
16	4.7	6.1	7.7	9.2	10.8	12.4	13.9	15.5	17.1	18.7	20.3	21.8	23.5	25.1	26.7	28.2	29.9	31.4
17	4.9	6.5	8.2	9.8	11.5	13.1	14.8	16.5	18.1	19.8	21.5	23.1	24.9	26.6	28.3	30.0	31.7	33.4
18	5.2	6.9	8.7	10.4	12.2	13.9	15.7	17.4	19.2	21.0	22.8	24.5	26.3	28.2	29.9	31.7	33.5	35.3
19	5.5	7.3	9.1	10.9	12.8	14.7	16.5	18.4	20.2	22.1	24.0	25.8	27.7	29.7	31.5	33.4	35.3	37.2
20	5.8	7.7	9.6	11.5	13.5	15.4	17.4	19.3	21.3	23.3	25.2	27.2	29.2	31.2	33.2	35.1	37.1	39.1
21	6.1	8.0	10.1	12.1	14.2	16.2	18.2	20.3	22.3	24.4	26.5	28.5	30.6	32.7	34.8	36.8	38.9	41.0
22	6.4	8.4	10.6	12.6	14.9	17.0	19.1	21.2	23.4	25.5	27.7	29.8	32.0	34.3	36.4	38.5	40.7	42.9
23	6.7	8.8	11.1	13.2	15.5	17.7	20.0	22.2	24.4	26.7	29.0	31.2	33.5	35.8	38.0	40.3	42.5	44.8
24	6.9	9.2	11.5	13.8	16.2	18.5	20.8	23.1	25.5	27.8	30.2	32.5	34.9	37.3	39.6	42.0	44.3	46.7
25	7.2	9.6	12.0	14.4	16.9	19.3	21.7	24.1	26.5	29.0	31.4	33.8	36.3	38.8	41.3	43.7	46.2	48.6
26	7.5	9.9	12.5	14.9	17.5	20.0	22.5	25.0	27.6	30.1	32.7	35.2	37.8	40.4	42.9	45.4	48.0	50.5
27	7.8	10.3	13.0	15.5	18.2	20.8	23.4	26.0	28.6	31.3	33.9	36.5	39.2	41.9	44.5	47.1	49.8	52.4
28	8.1	10.7	13.4	16.1	18.9	21.5	24.2	26.9	29.7	32.4	35.2	37.8	40.6	43.4	46.1	48.8	51.6	54.3
29	8.4	11.1	13.9	16.7	19.5	22.3	25.1	27.9	30.7	33.6	36.4	39.2	42.1	45.0	47.8	50.6	53.4	56.2
30	8.7	11.5	14.4	17.2	20.2	23.1	26.0	28.9	31.8	34.7	37.6	40.5	43.5	46.5	49.4	52.3	55.2	58.2
40	11.5	15.3	19.2	22.9	26.9	30.7	34.6	38.4	42.3	46.1	50.0	53.9	57.8	61.7	65.6	69.4	73.3	77.3
50	14.4	19.1	23.9	28.7	33.5	38.3	43.2	47.9	52.7	57.6	62.4	67.2	72.1	77.0	81.8	86.6	91.5	96.3
1° 00	17.2	22.9	28.7	34.4	40.2	46.0	51.7	57.5	63.3	69.0	74.8	80.6	86.4	92.3	98.0	104	110	115
1 10	20.1	26.7	33.5	40.1	46.9	53.6	60.3	67.0	73.8	80.5	87.2	93.9	100.7	107.5	114.3	121	128	134
1 20	23.0	30.5	38.3	45.8	53.6	61.2	69.0	76.6	84.2	91.9	99.6	107.3	115.1	123	131	138	146	154
1 30	25.8	34.4	43.0	51.6	60.3	69.0	77.7	86.1	94.7	103.4	112.0	120.7	130	138	147	155	164	173
1 40	28.7	38.2	47.8	57.3	66.9	76.6	86.3	95.6	105.2	115	124	134	144	153	163	173	182	192
1 50	31.6	42.0	52.6	63.0	73.6	84.2	94.9	105.2	115.7	126	137	147	158	169	179	190	200	211
2 00	34.4	45.8	57.4	68.9	80	92	103	115	126	138	149	161	172	184	195	207	218	230
2 30	43.0	57.3	71.7	86.0	100	115	129	144	158	172	186	201	215	230	244	259	273	287
3 00	51.6	68.8	86.2	103.2	120	138	155	172	190	207	224	241	259	276	293	310	328	345
3 30	60.2	80.4	100.5	120.5	141	161	181	201	221	241	261	281	302	322	342	362	382	402
4 00	68.9	91.8	114.8	137.7	161	184	207	230	253	276	299	322	345	368	391	414	437	460

APPENDIX No. 39.

Description of implements devised by Assistant Henry Mitchell for collecting specimens of bottom in alluvial harbors.—(Sketch No. 40.)

BOSTON, *September* 30, 1860.

DEAR SIR: The two instruments used on the Boston flats consist in the main of long steel rods about half an inch in diameter, terminating in specimen cups, the covers of which are opened and closed by the observer in turning the rods or shafts. Each is furnished with a thin metal disk, fitted with a spring on the shaft, so as to mark the depth to which the probe enters the mud. Figures 1 and 2 (Sketch No. 40) represent the probes with their specimen cups closed, as they would be when the shafts are to be thrust into or drawn from the bottom under examination. Figures 3 and 4 show the same instruments when open to receive specimens.

In Figures 1 and 3 the shaft, covers, and extreme point of the spear are one piece; but the main portion, or the hollow spear head itself, is movable, and may be easily turned about the shaft which passes through it. When this instrument is pushed into the mud to the required depth, the observer turns the shaft with a handle, (not shown in the sketch,) and by so doing uncovers the specimen boxes, the spear head meanwhile, by reason of its form, resisting the circular movement. The sharp edges of the covers offer little resistance, and move freely. By reversing the motion the observer again covers the cups of the spear head, and then draws up the instrument.

The form shown in Figures 2 and 4 differs from the other in several particulars. The specimen cup and shaft are of one piece, and the cover is movable up the shaft by a fine screw thread. The thin blades or wings attached to the cover resist the circular motion given to the shaft and cup by the observer, and thus the cup is opened or closed. This instrument is preferable to the other for obtaining specimens of pure mud, since the cover may be screwed tight, and the specimen drawn up through other strata without mixing at all with them.

Yours respectfully,

H. MITCHELL, *Assistant Coast Survey.*

Prof. A. D. BACHE, *Superintendent U. S. Coast Survey.*

APPENDIX No. 40.

Description of the method of applying a new form of dividers invented by Mr. John R. Gilliss for the graphical decomposition of tidal curves.—(See Sketch No. 40.)

COAST SURVEY OFFICE, *September* 29, 1860.

DEAR SIR: I enclose a sketch of a pair of dividers devised by Mr. John R. Gilliss, principally for use in decomposing graphically the tidal curves, but which can also be used with advantage for all purposes for which halving dividers are required.

The most laborious part of our process of decomposing graphically the tidal curves into their component diurnal and semi-diurnal waves is the taking of the mean between the ordinates of the curve of observation at points twelve lunar hours apart, for the purpose of eliminating the diurnal wave. It is done by tracing the curve on a piece of transparent paper, and then sliding it twelve hours forwards or backwards along its horizontal axis. Then the difference of the ordinates of the two curves thus superposed is measured at short intervals with proportional dividers, or so-called "wholes and halves" dividers. At each measurement the dividers are

reversed, and the half of the distance between the two curves is pricked off. These points then joined by a continuous curve represent the semi-diurnal wave.

This process can be gone through much more rapidly with the dividers proposed by Mr. Gilliss.

As you will see by the sketch, they are formed of three branches, the middle one of which is always kept at equal distances from the two others by two diagonal braces. Slots in that branch at C and B (Sketch No. 40) allow it to rise as the dividers are opened, and a small spiral spring at B keeps the point drawn back from the paper until the two outside branches are placed on the points wanted, when a pressure with the finger on the head at C will cause the middle leg to prick off the middle point.

A spring between the outside legs near the joint C serves to keep them always open, so that the position of the fingers in holding the instrument need never be changed. Instead of this, rings might be adapted on the outside for the thumb and middle finger, the forefinger being kept on the head at C.

With either arrangement a person will be enabled to work with great rapidity after a little practice.

Very respectfully, your obedient servant,

L. F. POURTALES,
Assistant Coast Survey.

Prof. A. D. BACHE, *Superintendent U. S. Coast Survey.*

APPENDIX No. 41.

Report of Lieut. Comg. Alexander Murray, U. S. N., Assistant Coast Survey, relative to the Labrador eclipse expedition, and to incidental results bearing on the hydrography of the coast of Labrador.—(Sketch No. 38.)

U. S. SURVEYING STEAMER BIBB, *New York, August* 12, 1860.

SIR: When your telegram was received, on the 16th of June, intimating the probability of the detail of the steamer Bibb for conveying the astronomical expedition to Labrador, the vessel had been only four days in port, having just then closed a long and active period of duty at the south. Under the emergency which had arisen, extraordinary means were at once applied, though the Bibb then needed repairs, and I was happy to feel not entirely unprepared when I received your final instructions for that duty on the 22d of June. All needful preparations having been made, and the party of observers in charge of Professor Stephen Alexander on board, on the 28th we availed ourselves of a fair tide, taking our departure from the navy yard at 11.30 a. m., and entered upon the voyage. The weather was fair on our passage to Sydney, (Cape Breton island,) but a sad event occurred on the night of the 29th in the loss overboard of John McCalmut, one of the seamen of the Bibb.

The vessel arrived at North Sydney (the coal depot) at midnight on the 2d of July. During the fine weather of that part of the voyage advantage had been taken to organize for the observations according to your programme, and to arrange the preliminaries for our work to meet the several contingencies pointed out by your instructions. A mutual good understanding then had, remained unbroken during the expedition.

The distance from Sydney to Cape Chudleigh and back being about 2,400 miles, it became necessary, on account of the limited capacity of the steamer, to have coal deposited at some intermediate point; and Domino harbor was chosen, in latitude 53° 28′ N., and means were

taken to insure the delivery of the supply that would be required for the return of the vessel. We left Sydney on the night of the 3d, with as much coal as could possibly be taken on board. No pilots could be had for the coast north of Belle Isle, and hence that resource might well be regarded as vital to the success of the expedition, more especially as in the very stormy weather that met us in the Gulf of St. Lawrence our entire deck load of coal was endangered.

On the 7th of July the Bibb passed the light-house of Belle Isle, and proceeded along the coast of Labrador. Icebergs were constantly in sight, but not so numerous as to obstruct navigation. The weather continued pleasant until the morning of the 10th, when a stiff breeze from the southward and eastward set in, with a tremendous sea. Towards evening the fog began to settle down, and the icebergs to drift towards the land. We sought a harbor, and at 10 p. m. anchored behind an island in latitude 56° 43′ N., which afforded shelter from an impending storm. The weather continued thick and stormy until the afternoon of the 11th; but, in consideration of the main object of the expedition, the accomplishment of which was hazarded by each delay, I determined, after advising with Lieutenant Ashe, R. N., who had joined the party at New York, to take the inside passage and push on, the fog still remaining outside, and the ice being pressed close in along the islands. We had in this way made some forty miles when the only accident occurred that was worthy of record in the voyage. While under the least possible pressure of steam, and carefully feeling her way, the vessel ran upon a ledge of sunken rocks, but with the aid of her anchors was got off at the return of the tide, and again headed on her course, being at meridian, again in the open sea.

On the 13th of July, when approaching our final destination, the navigation was again interrupted by reefs, over which the sea broke with great violence. We were then nearing the point where the middle of the shadow of the eclipse was to pass, and, as the time pressed, it became imperative to pass the reef just mentioned, in search of a harbor. The outer line, ten to twelve miles from shore, was easily passed through, and approaching the land cautiously, we entered, about midnight, into a channel which proved to be the north inlet at Aulezavik island, and anchored in latitude 59° 54′ N. early on the morning of the 14th of July. At meridian of that day a site for an observatory had been selected by the chief astronomer of the expedition, Professor Alexander, and before the close of evening the material for the structure, and the tents for magnetic, tidal, and meteorological instruments, were landed. A tide-staff was also set up, and observations commenced; but, with this exception, operations were suspended until the afternoon of the 16th by a heavy gale of wind, with prevailing rain. At night all the instruments were in their appointed places, and the scientific work was in full progress under the respective heads.

The tenor of your instructions as to my first duty being "to convey the astronomers and other officers of the Labrador eclipse expedition to the vicinity of Cape Chudleigh, the delays incidental to hydrographic work were not allowed to interfere with the execution of the first object; but that done, my attention turned to the kind of duty usual in the party under my command in the steamer Bibb. A base line having been measured with care, the inlet in which we landed, and which has been named Eclipse harbor, was sounded out. In conjunction with Professor Venable and Mr. Lieber, other explorations were made, and the results, as well as the survey just referred to, are shown in the accompanying sketches. An exhibit is made, in a third sketch, of the soundings and ocean temperatures taken on the eastern coast of Labrador. The surface temperature was found to be coldest where the water was deepest and the current strongest, reversing in the "Labrador current" the characteristics of the "Gulf Stream." Most of the icebergs are confined to the line of drift marked on the sketch; those that are not being merely fugitive ones. These sometimes lodge on sunken reefs, and serve as beacons; the wearing of the tides leaving projections above, so that they may be known and used as such.

After a terrible storm, which raged three days, and during which the barometer fell to 28.4 inches, the Bibb left Eclipse harbor on the 24th of July, and on the 27th reached Domino harbor. This is a small and compact fishing station, affording natural wharfage, the vessels resorting to it being moored to the rocks. Here we found the schooner which I had appointed to meet us with a supply of coal. In order to profit by good weather, the steamer got under way, after determining the position of the harbor, and continued the general hydrographic observations with the smaller vessel in tow; but towards evening, on the 29th, both were sheltered in Chateau bay from a severe southwest gale. The bay just named is also a fishing station, and is a very good harbor. There we took in coal from the schooner, and on the morning of the 31st left for Sydney, where we arrived on the 2d, and, sailing next day, the Bibb reached Newport, R. I., on the 7th of August, where the officers of the expedition met you in person. The vessel then proceeded to New York, and was put into the dry dock, in consequence of her leaky condition.

I am much indebted to Lieutenant Ashe, of the royal navy, who, on all ocasions, was ready with aid which was invaluable to us in navigating the coast of Labrador.

The deprivation of ordinary comforts was very cheerfully borne by the scientific members of the expedition, and I was surprised and flattered by the manner in which they met the inconveniences of crowded sea life.

Under separate heads I shall now briefly state the results of observations incidentally made on the coast of Labrador.

Fogs.—The experience of the hydrographic party in the steamer Bibb goes to show that in July the fog on the coast of Labrador is neither so dense, so frequent, nor so enduring as those that beset the Bay of Fundy and the northern section of our own coast at the same season.

Winds.—Calms were of short duration, seldom lasting more than a single day. The gales were frequent and very violent. Near Cape Chudleigh they invariably sprung up from the southward and eastward, and generally ended in the southwest—the southeast being of longest duration, the southwest the most violent. The gale which ended on the 23d of July went round the compass from southeast, by way of the north, to southwest, and was the worst gale experienced on the coast. It extended far to the southward, and wrecked many vessels in the Gulf of St. Lawrence.

South of Domino harbor all the gales of this summer, up to the 1st of August, were said to be from S.SW.

Ice and snow.—Ice formed in Eclipse harbor, behind Aulezavik island, on the morning of the 14th of July. Part of the western shore had an "ice foot" three to four feet thick, which remained during our stay, and immense fields of ice lay on the sides of the mountain, from which streams of water ran constantly. On the night of the 22d a snow storm covered the region adjacent to Aulezavik, but its traces disappeared in latitude 54° N.

Tides.—At Eclipse harbor the rise and fall of the spring tide which occurred on the 18th of July was 5.7 feet; the rise above the beach mark being 4.5 feet, and the fall 1.2 feet below it. The estimated mean rise and fall is 5.1 feet.

At Nukasusuktok island, latitude 56° 34′ N., as estimated by beach-mark made on the 10th of July, the mean rise and fall is	5.0 feet.
Mean rise and fall at Domino harbor	2.9 "
Mean rise and fall at Chateau bay	4.0 "

The highest tide observed at Eclipse harbor occurred during the gale of the 22d and 23d of July.

If from this brief account of a short but eventful period of duty anything can be gleaned

either of interest to science or useful to navigation, I would reckon it with the gratification of having assisted in carrying out your wishes in regard to the Labrador expedition.

Very respectfully, your obedient servant,

ALEX. MURRAY,
Lieutenant U. S. N., Assistant Coast Survey.

A. D. BACHE, L.LD., *Sup't U. S. Coast Survey.*

APPENDIX No. 42.

Notes on the geology of the coast of Labrador, by Oscar M. Lieber, esq., August, 1860. (*Sketch No.* 38.)

DEAR SIR: In tendering to you this report on the geology of Labrador, or rather of its coast, I have great occasion to regret that the necessary speed in hurrying on to the point where the eclipse observations were to be made, and the equal expedition of our return voyage, prevented me from obtaining more than very passing observations on the geognostic conformation of this far northern region. The only points at which we stopped going north were at Nukasusuktok island, near Nain, where a fog delayed us, and at the termination of our outward bound voyage, Aulezavik island. Returning we visited Domino and Chateau harbor, in Temple bay, both in the more southern portions of Labrador. These four localities are the only ones therefore which it was possible to inspect accurately. Still, we generally hugged the coast so closely, and this coast itself is so bold and precipitous, that, knowing these four points from absolute local inspection, I found little difficulty in seeking to form a correct idea of the construction of the intermediate spaces. Yet, notwithstanding that much interest naturally attaches to the petrography of a region so little explored and so rarely visited, it is less in regard to the constituent varieties of rocks than in connection with the powerful effects of forces acting upon the surface, and rendered peculiarly energetic by the rigid climate, that we are enabled to study the most instructive phenomena.

I accompany this report by a chart (see Sketch No. 38) of the coast of Labrador, compiled from the best authorities at my disposal,* on which I have traced the boundaries of the different rocks observed by me. These are very few in number.

Proceeding northward from the Straits of Belleisle we have first a coarse quartzose gneiss, which is seen at Temple bay, (or Chateau bay,) and at Domino, and appears to extend northward to a point between Caluileweet. and Nain, perhaps to Davis's inlet. North of this we have the coarse porphyroid granite of Nain, which extends probably to Okkak island, or a point between that and Cape Mugford. North of this again we have the gray syenitic gneiss of Aulezavik, which embraces the extensive region from Mugford to Chudleigh.

I. *The gneiss of Domino* and the region north and south of it is of the very coarsest description; the beds are very thick, and though often distinctly marked by different composition and color are frequently very much severed by jointure planes and fissures. At times entire beds are composed of quartz, with very little foreign material, and of a pinkish cast. Other beds abound in hornblende, and it is this mineral no doubt which at Domino has given rise to the belief in the presence of coal, in consequence of which, I was informed, some slight explorations had been made. These hornblendic beds sometimes certainly do resemble coal very much in appearance. A very striking instance of this is afforded by one of the most eastern of the Esquimaux islands, a little rock which rises boldly from the sea, and is shaped like a lady's flat, the band being represented by the dark hornblendic bed. At least such I feel safe in considering it after inspecting the more southern regions of Spotted island and the Isle of Ponds at Domino harbor.

* These were the Admiralty chart of the western half of the north Atlantic, and a manuscript chart politely loaned to me by Mr. Cyrus W. Field, and sent to him by the colonial government of New Foundland—both corrected from our own observations.

A large white quartz vein crops out on the Isle of Ponds east of the harbor, which, especially as it occurs in the vicinity of a body of dioritic porphyry which crests the hill, may at some future period possibly be found to contain useful metals.

Such dioritic rock also occurs at Chateau bay, where the entrance, or "tickle," as it is locally termed, penetrates through it. This is the only rock I saw in Labrador to which an eruptive origin might be ascribed. The strike of the gneiss of Domino is generally northerly, the dip easterly, at an angle of 15° to 45°.

This rock presents the least boldly marked coast of any found in Labrador; and although the hills, sometimes rising to 600 feet, (as in Chateau bay,) strike us as bold and formidable when coming from the United States, or even Nova Scotia, and especially after passing along the low shore of Newfoundland, they appear very tame and insipid after our eyes have rested on the lofty and precipitous coast of the more northern portion of Labrador. A view of Battle island and vicinity (see Sketch) will furnish a very fair general idea of the character of the coast where this rock prevails.

The less disrupted nature of the surface of this rock appears to offer peculiar facilities for the accumulation of water in ponds, which serve as receptacles for delicious salmon trout. From these the Isle of Ponds derives its name.

Owing rather to the more southerly latitude than to any greater fertilizing capacity of the rocks, more vegetation occurs in this region than in those to whose description we are about to proceed. The soil is a kind of swamp-muck, at times true peat, very much like the soil of the inland portions of some of the Savannah river rice plantations. At Chateau harbor I found very luxuriant tufts of grass, some lilac-colored lilies, the dogwood growing only about two inches high, however, and exhausting all its energy in the development of one flower—besides quite an abundance of stunted firs, about twenty feet high, so closely interwoven with their low branches that it was almost impossible to penetrate and pillow the feet in the ankle-deep moss whose pale green tint relieves the sombre colors of the firs. An occasional birch may also be seen, as well as elder and mountain ash.

II. *The granite of Nain.*—I have already indicated the vicinity of Caluileweet as the probable boundary between this granite and the gneiss region just described. We first saw it on one of the smaller islands near Nukasusuktok island, and subsequently I enjoyed an opportunity of examining it on that singularly-named island itself. In passing through the archipelago in the neighborhood of Nain, fine opportunities were afforded for studying its scenic features, as well as the particular topography to which it gives rise. Numerous conical rocks, shaped like bee hives or hay stacks, stud the tranquil waters, which are protected from the swell of the ocean by others lying further seaward. These inaccessible hills appear to attain a pretty uniform elevation of three or four hundred feet, while I should roughly estimate the height of the most prominent mountains of the main land, whose precipitous sides descend unbroken to the water's edge, to be about twelve hundred feet, the average height of the littoral face being approximately five hundred feet.

Bold as this coast is, there are not many single mountains visible from the water so conspicuously individualized by a freely traced outline as to appear in a drawing with the striking effect which they produce upon the eye of the actual beholder. The summit outline is generally too even—too little serrated—to appear to advantage in a picture; so that almost all the sketches I took from the hurricane deck of the steamer Bibb, while she was gliding along the tortuous sound of Newark island, would fail to furnish more than a very tame idea of the character of the scenery. I venture to select but one. The clearly pencilled outline of the notched mountain, which guards the entrance of Port Manvers, certainly presents a fit subject for a sketch. Its peculiar shape, when seen as the drawing represents it, from the north, is so very striking that such a sketch may be of service to the navigator. The sharp, angular notches on the eastern slope—the unbroken inclined plane west of the summit, uniting further on with

the outlines of the numerous islands of the group, and connecting also with the nearer, more northern cliffs of Orton island, (not seen in the figure)—all these are features which must impress themselves indelibly upon the eye of the beholder. Scarcely less conspicuous and unmistakable are the clearly traced patches of snow-drift on its face, which I have endeavored to delineate with the utmost care, because evanescent as they might at first thought appear, it is scarcely possible that such really should be the case, since they necessarily must adapt themselves to the inequalities of the surface; so that they may well be regarded as reliable land marks during those seasons of the year in which the entire surface is not equally whitened. I have represented the "Bibb" as passing through the inlet for the purpose of indicating its whereabouts in the drawing.

The southern and southeastern sides of this mountain present no equally striking outline, although its elevation and snow-furrowed sides render it, even when viewed from those points, sufficiently conspicuous for nautical purposes. After sighting it, however, it may be better to adopt a more northern or northeasterly course for the purpose of avoiding the islands, though no doubt with experience as a guide they might be penetrated with comparative safety, for along the entire coast the water is deep and navigable.

The granite belonging to this region is extremely coarse, and often hornblendic in its composition, approximating therefore to syenite. The felspar is generally of a pale flesh color, and appears to be orthoclase. It seems, however, that this is the rock which contains the most beautiful of all felspars, to which the country has given its name, the *labradorite.* I am inclined to believe that I found a minute particle of this mineral at Domino, but it was too small to enable me to satisfy myself, and I cannot, not even admitting this instance, regard it as also regularly belonging to the gneiss of that region. On Newark island, however, or at least on one of the islands of the same group, one of our sailors picked up a very handsome piece, now in the possession of Lieut. Ashe, R. N.; and the absence of more numerous discoveries I can ascribe only to the short time which could be devoted to this region, and the necessarily very insufficient search. I am additionally induced to consider the vicinity of Nain as the true locality of the "labradorite," because Nain is the only spot in Labrador outside of the Straits of Belleisle where white men are permanently settled and remain throughout the year. That cod fishermen on their annual visits to the southern portion of the coast should preserve and transmit specimens of this mineral is certainly far less probable than that intelligent Moravian missionaries from the self-sacrificing little colony of Nain should collect the curiosities of their neighborhood and transmit them to Europe for scientific investigation.

It is nevertheless evident that this felspar is rare even here, and that the flesh color variety prevails. The quartz of the rock is whitish and rather vitreous, the mica and hornblend black.

In a generous climate this rock would produce fine arable soil. Here this is, of course, not the case. Decomposition is barely noticeable in its effects, although the frosts and thaws exert a powerful disintegrating influence. The absence of level land at the base of the hills prevents this crumbling rock from accumulating to any extent, and it is only in the valleys that a few straggling firs of stunted growth may be seen. The various mosses thrive as a matter of course, while lichens of black and orange color contribute to enliven the landscape a little; and though the graceful wild lily of Chateau bay has entirely disappeared, quite a handsome nosegay may yet be gathered from the moss-meadows of the rugged islands near Nain. On Nukasusuktok island I first saw the little scarlet moss which clings to the surface of the snow, and has caused the latter to be termed "red snow."

III. *The gneiss of Aulezavik.*—As we wend our way further northwestward the formidable rocks of Mugford island soon rise to view. The jagged crest of these bold cliffs may, indeed, be seen long before the mountain at Port Manvers has disappeared below the horizon. We notice it first when it presents the remarkable outline shown in the drawing, (Sketch No. 38.)

It is then distant about 20 miles, bearing NW., and no one could possibly fail to recognize its ragged surface.

From Mugford northward we observe an infinitely greater variety of form in the outlines of the mountains than that which prevails further south; and since this irregularity and diversity continues on to the region of Aulezavik, which alone, in this portion of Labrador, I had an opportunity of examining, there seems to be good reason to consider the petrographic region of Aulezavik as commencing near that point.

Most conspicuous and most surprising in all this profuse irregularity is the crater-shape, which constantly reappears in all its individual variety. I first observed this in the region south of Cape Niakungo, a portion of which I have figured, (see sketch,) as seen at a distance of about twenty miles. One of the crater-shaped mountains is there exhibited standing on a great plateau high above the level of the sea. Except in other portions of Labrador itself I question whether there are many parts of the world which could exhibit equal variety in contour within the few miles here represented, and, considering that this illustrates but one instance of the constantly recurring volcano-like cones, it will not appear surprising that we all imagined that we there beheld the mighty evidences of extinct volcanic action. To me some of them appeared very closely to resemble the cuts of the trachytic group of the Auvergne. The deeply packed snow in the depression increased the effect; but we did not then take into sufficient consideration the immense power which the untempered climate of these regions wields.

It has been said that the crater-shape is often repeated. A mountain in the southern part of Aulezavik island, seen in the drawing, (Sketch No. 38,) at a distance of about six miles, affords a remarkably fine illustration. Again, the white snow relieves the interior, and it is certainly very difficult to convince ourselves that this is not an ancient volcano. Still the nature of the rock utterly prevents this supposition, for it is simply a syenitic gneiss. We shall again recur to the probable cause of this crater-shape, but for the present devote our attention to the character and composition of the rock.

Syenitic gneiss is the true rock of the region, the normal one, although so many modifications occur that entirely new rocks are produced; rocks having no direct connection with the basic syenitic gneiss. In consequence of this we have beds in which quartz alone occurs, or beds entirely occupied by the red felspar of the region, as is seen with very beautiful distinctness in some of the dangerous Pikkintit islands. Again, some beds are composed of white quartz and tourmaline, as in Norway, others contain scarcely anything but black tourmaline, or tourmaline and garnets. Some are composed of green hornblend, approximating to actinolith. From this there seems to be a passage into a coarse diorite rather porphyroid in its character, but occurring in regularly intercalated beds, not in dykes, and evincing no sign of an eruptive origin. Again, some beds are composed of quartz and garnet, while others are studded with a beautiful golden-colored mica. A rock which appears identical with aphanite, although not at all igneous, I also found. Yet, with all this apparent variety,* the transitions are too gradual to permit the differences to leave any effect on the landscape. The gneiss is uniformly grey, upon close inspection; but in the landscape the entire mountain masses receive a bronze color, but little dimmed even by great distances in the clear, and, from its very clearness, to our unaccustomed eyes, deceptive atmosphere.

The Vandyke brown of the wild mountain groups is relieved by nothing but the white snow. No tree is there. The orange colored lichen, which we saw at Nain, has disappeared, and patches of a black one alone remain to deepen the shading. Still, in some of the level places, the snow moistened moss meadows flourish, and lend their gentle green or soft yellow to diversify and mellow the rough outlines of the landscape, while the shallow rays of the northern

* Mr. Nones found a small piece of fossiliferous limestone on Aulezavik island, but this belongs to a more northern region.

sun, penetrating through the leaves of the ruby sea weed on the beach, often recall colors which belong to a more genial clime.

But these are comparatively exceptions to the rule. The impression made upon our minds is that all organic nature has been banished from the spot. Not as we conceive it to have been in the early days of creation, when the inorganic kingdom also seemed to be kept in abeyance and the land scarce rose above the water, but, as if in the absence of all softening, subduing vegetation and stirring life, the very rocks revelled in their freedom. In a view of the wild mountains in the interior of that portion of northern Labrador which lies between Aulezavik island and Ungava bay, as seen from a mountain side above the magnetic tents, I have endeavored to convey some impression of the nature of this dreary spot. I allude to one of the drawings enclosed, (Sketch No. 38,) but an abler pencil is required to do justice to its savage grandeur.

The wild irregularities of this country are produced in part, in part perhaps only increased, by several different causes. In the first place the rude stratiform character of the rock is really better adapted to the production of angular and distorted outlines than a compact, unstratified structure. As far as my experience goes, gneiss always furnishes bolder contours and more precipitous cliffs than granite, provided, of course, that the general level of the country is sufficient to admit such extremes. Nor is this surprising when we consider that irregular surfaces are the result of counteracting forces, whether these be the extreme hardness or cohesion of the rock on the one hand, and force exerted by erosion on the other, or the tendency towards a definite and often parallel fissure formation in the first place, counteracted by an irregular fissure formation, produced by totally different causes. Hence it may, I think, be safely set down as a geologic law, that, *with equal degrees of hardness in the rock itself, stratification, cleavage, or jointure planes will increase rather than diminish the irregularity of the surface.* Only where these are horizontal may it sometimes occur that this rule does not hold good. In the present instance the dip is generally vertical, the set a high angle southward, the strike principally to the north.

This, therefore, to commence with, may be regarded as a prominent cause of irregularity, and the infinitely less elevation of the more southern gneiss region of Labrador can alone be assumed as a cause of the much more undulating nature of the surface, notwithstanding that the same general circumstances as to the nature of the rock exist there also.

A second cause of the irregularity of surface here is to be found in the tremendous force of the frost of a Labrador winter, the influence of the heavy covering of snow, and very probably also the former existence of glaciers, all of which we shall presently take occasion to discuss.

In addition to all this, we find that the absence of all vegetation in this triste and barren region deprives the landscape of that subduing roundness produced by foliage, to which we, inhabitants of kinder countries, are accustomed.

The effects of frost are manifested in a singularly forcible manner. The entire surface, where it is not too steep to enable debris to collect, is covered with broken masses of rock, cubes of ten feet and less scattered in wildest profusion. Sometimes a patch of moss, the grass and heather of this country, fills up the crevices, but generally we may look down into them far and deep without ever detecting the base upon which the blocks rest, hurled aloft, as they appear, by the hands of Titans. In scaling, in company with Mr. Venable, the summit of Mount Bache, on an occasion intended mainly for taking its altitude barometrically, we enjoyed the finest opportunities for studying this phenomenon. The summit and sides of the mountain present few steep precipices. I speak comparatively only, and in reference exclusively to northern Labrador. Yet, scattered helter-skelter over all, and piled up in endless number, the whole surface is covered with such loose rocks. The difficulties of locomotion may readily be conceived. In scarcely a single instance did we see the gneiss beds still in situ, and in the only one or two exceptions some giant wedge seemed to have driven them

asunder. Yet none of the blocks were rounded. Attrition of no kind had influenced them to any perceptible extent, neither had atmospheric influences altered the color, hardness, and composition of their exteriors; it was simply a wilderness of unchanged blocks of the gray gneiss.

There was a puzzle. Whence came these broken rocks? There was no higher spot whence they might have fallen. The slight protrusion of the uptilted beds of gneiss in situ, to which I have referred, alone seem to have been permitted to remain for the purpose of instructing us. Clearly, that force which had riven its beds asunder, no other than the *frost*, had broken the rest from their foothold and prepared them for removal by another coming into play at a later season; the thawing, downward-gliding *snow*. Many of the blocks were probably but slightly moved from their original position, perhaps barely turned over or merely forced a little out of place. Yet the effect to the eye of the beholder would be as great as if they had been transported hundreds of miles.

When we descended from the mountain we crossed over a broad patch of snow, deeply packed,* which clearly taught us how the rocks were moved. In truth, this was a miniature glacier and a regular morrain was piled up along its edge. It is impossible for us to form any estimate of the amount of snow which may fall per square foot in a winter, but from the fact that such quantities were still remaining late in July, and certainly they never altogether thaw away, we may reasonably infer that during its downward progress, either as snow or water, a tremendous force must be exerted, a force quite sufficient to account for the characteristic surface phenomenon just described.

But to the snow may also, I believe, be referred the still grander effect evinced in the production of the crater-like concavities. This crater shape is not confined to the mountains here. We frequently observe it with icebergs, and it is probable that in both cases the cause may be a similar one. Commencing with a more or less irregular surface, when it breaks loose from the Arctic glaciers, the melting ice sends little streams down the inclined planes of the surface of the berg. In the depression water collects and expedites the melting of the ice beneath and around it, while those portions from which the water is drained are necessarily melted much slower, so that the two extremes are increased until we have bergs resembling craters, turrets, castle ruins, and irregular shapes of all kinds. A similar process may, in the course of time, produce the crater-shaped mountains, some chance circumstance of superficial form first determining the bed of the accumulating snow and the course of the water trickling from it. This explanation is certainly, I admit, not very clear nor very conclusive, but we must remember several other matters. In a region where the surface is too rough to admit of rivers or streams to any extent, where enormous masses of snow accumulate in the depressions and lie there during the greater part of the year, they may very naturally be supposed capable of producing effects unknown to any similar extent in milder climates. Besides the two great *levellers*, soil and vegetation, are absent.

To what extent actual glacial action may at one time have prevailed it is difficult to say. The numerous inlets about Nain are certainly singularly like the Scandinavian fiords, which are regarded as the beds of ancient glaciers; and it would require no great stretch of the imagination to conceive the sound of Aulezavik island to have been the same, especially as it is separated from the north entrance by shoal waters and a reef of rocks, exposed at low water. A closer examination of this singular coast would teach us some great truths, no doubt, and be able to clear up much which is still quite unexplained in regard to the glacial period. Unfortunately my time was too short to enable me to discover anything substantial and satisfactory in this respect. Besides, an examination aiming at a full determination of all facts connected with this and similar inquiries should seek its field of observation in the interior perhaps quite

* Some of this snow was as much as 20 feet deep, and while we were at the top of the mountain snow fell. We were in a snow storm at the level of the sea as late as the 22d of July.

as much as along the coast, where the icebergs, sent down from the further north, and the floes and great ice-pack, which even we saw at a distance from the summit of Mount Bache, are driven along the shore by the current of Baffin's bay and Davis's straits, and in part find their way into the Strait of Belleisle, forced westward by the current which sets into the Gulf of St. Lawrence, all contribute to obliterate the evidences of more ancient action.

I hope that this sketch may assist you in forming some idea of the geologic as well as topographical structure of this coast, although I am sorry to be obliged to lay before you an account so meagre, and containing so little of ampler interest.

Your very obedient servant,

OSCAR M. LIEBER, *Geologist Labrador Expedition.*

A. D. BACHE, *Sup't. U. S. Coast Survey.*

APPENDIX No. 43.

Aids to navigation recommended in reports made to the Superintendent by Assistants of the Coast Survey.

Sect.	Object.	By whom recommended.	Date of report, &c.
V.	Buoys to mark channel and readjustment of bar buoys in Ossabaw sound, Ga.	Lieut. Comg. C. M. Fauntleroy, U. S N.	Reported May 4, 1860. (Appendix No. 12.)
V.	Change to mid-channel of buoys in Sapelo sound, Ga.	..........do..........do..........	Referred to Light-house Board May 7, 1860. (Appendix No. 44.)
VI.	Buoy to mark Tennessee shoal off Long key, Florida reef.	Lieut. Comg. J. Wilkinson, U. S. N....	Referred to Light-house Board July 7, 1860. (Appendix No. 14.)
VI.	Buoy to mark wreck off Grassy key, Florida reef.	..........do..........do..........	Do. do.
VI.	Bar and channel buoy and light for Gasparilla entrance to Charlotte harbor, Fla.	Lieut. W. R. Terrill, U. S. A	Reported April 20, 1860. (Appendix No. 31.)
VII.	Buoy on outer end of Redfish shoal, Pensacola bay, Fla.	Lieut. Comg. T. S. Phelps, U. S. N	Referred to Light-house Board June 4, 1860. (Appendix No. 45.)
VII.	Buoy on shoal off Garçon point, Pensacola bay, Fla.	..........do..........do..........	Do. do.
VII.	Buoy on outer end of Bartley's Point shoal, near Pensacola wharves, Fla.	..........do..........do..........	Do. do.

APPENDIX No. 44.

Letter to the Secretary of the Treasury, communicating recommendations from Lieut. Comg. C. M. Fauntleroy, U. S. N., Assistant Coast Survey, for changing the position of buoys in Sapelo sound, Ga.

COAST SURVEY OFFICE, *May* 7, 1860.

SIR: I have the honor to transmit herewith an unfinished proof of the chart of Sapelo sound, with sailing lines; also the suggestions of Lieut. S. Bent, U. S. N., in regard to buoys, as follows :

"Lieut. Fauntleroy's survey developes the existence of a much better channel than the one hitherto used, and, as the Sailing Directions are for this new channel, the buoys, in their

present position, become not only useless for the purpose they were intended, but dangerous from their liability to mislead vessels; and, at the request of Lieut. Fauntleroy, I have to suggest that the Light-house Board be recommended to have them changed to mid-channel buoys, and the outer one placed on the narrow neck or bar formed by the eighteen-feet curves on the new channel course, and the inner one at the point at which the course is changed, about a third of a mile to the northward and eastward of where it is now anchored."

I would respectfully request that a copy of this communication may be transmitted to the Light-house Board.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. HOWELL COBB, *Secretary of the Treasury.*

APPENDIX No. 45.

Letter to the Secretary of the Treasury, transmitting recommendations of Lieut. Comg. T. S. Phelps, U. S. N., Assistant Coast Survey, for buoys in the vicinity of Pensacola harbor, Fla.

COAST SURVEY OFFICE, *June* 4, 1860.

SIR: I have the honor to communicate, for the information of the Light-house Board, an extract from the report made by Lieut. Comg. T. S. Phelps, U. S. N., Assistant Coast Survey, on completing the soundings required in Santa Maria de Galvez bay, and connecting that work with the completed hydrography of Pensacola harbor:

"The vicinity of Garçon point is much frequented by ships and other vessels loading with timber, and, to render the navigation safe, I would recommend that two small buoys be placed, one in twelve feet water on the shoal which makes out from Garçon point, and the other in ten feet water, near the extreme point of Red Fish shoal. Two buoys only are required to render the anchorage a safe one."

"I would also recommend that a small buoy be placed on the extreme end of Bartley's Point shoal, which is a short distance to the northward of the Pensacola wharves, and extends out eastward about three-quarters of a mile. Vessels frequently ground there, which would be avoided if that dangerous locality were distinctly marked."

The enclosed tracing is a copy of one furnished by Lieut. Comg. Phelps, and I would respectfully request that it may be forwarded to the Light-house Board, with a copy of this letter.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. HOWELL COBB, *Secretary of the Treasury.*

INDEX OF SKETCHES.

1

NOTE.

It is deemed inexpedient at the present time, for obvious reasons, to publish for general circulation maps and charts Nos. 9, 11, 12, 14, 17, 18, 26, 27, 30, 31.

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